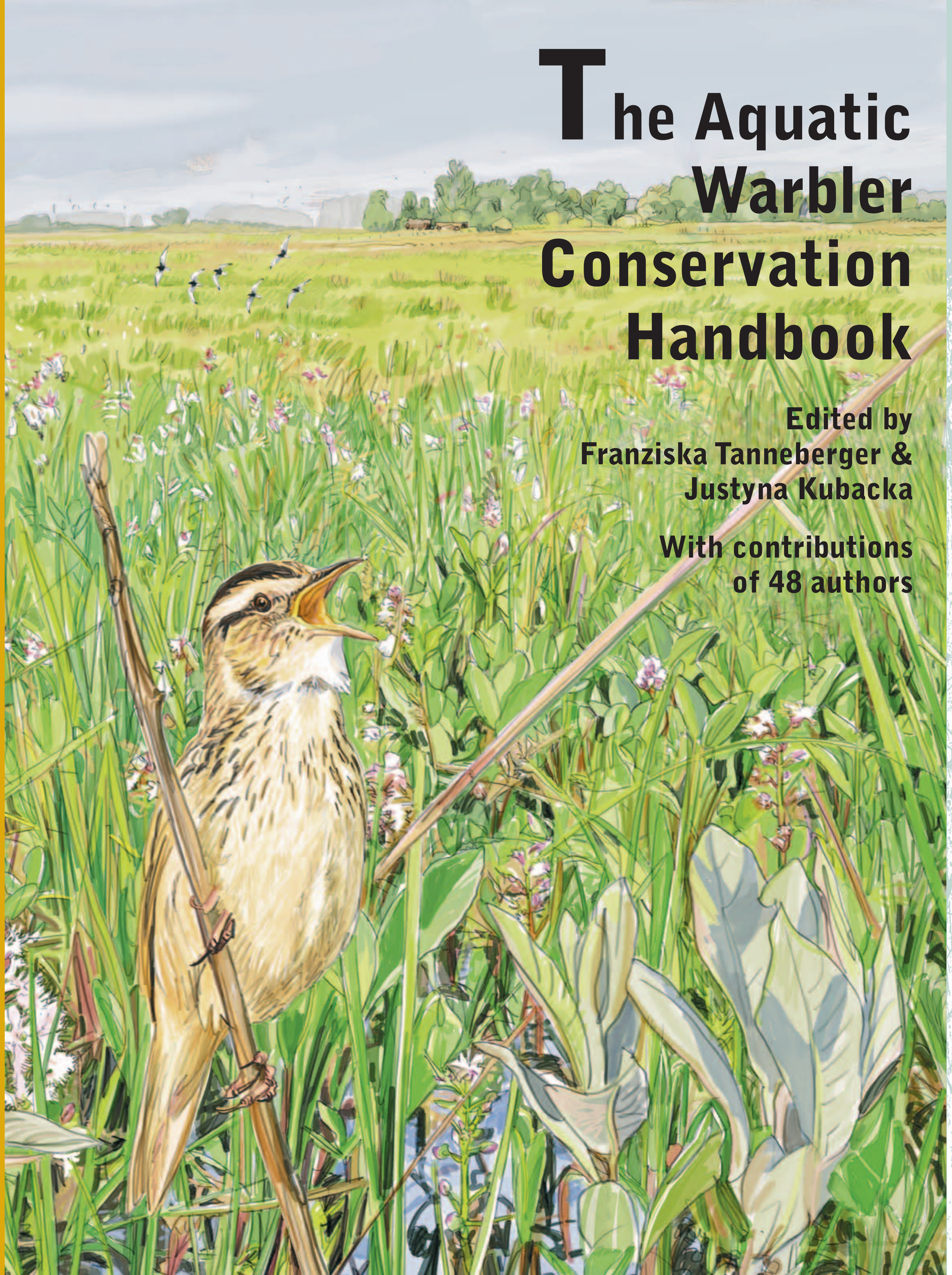

The Aquatic Warbler Conservation Handbook

Edited by
Franziska Tanneberger &
Justyna Kubacka

With contributions
of 48 authors

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Contents

Save the Aquatic Warbler and its fascinating homeland

The Aquatic Warbler is more than a rare, elusive, and enigmatic bird species. For various reasons, its survival in Europe is of outstanding importance. It is one of the few bird species that are largely endemic to continental Europe. It is one of the rarest European breeding birds and the only passerine species of continental Europe classified as Vulnerable at a global scale according to the IUCN Red List of Threatened Species. But probably even more important: it is a true flagship and umbrella species, a representative of natural or near-natural fen mires of the temperate zone. No other bird species is as strictly confined to sedge fen mires as the Aquatic Warbler, which, on the other side of the coin, was the main reason for its alarming decline. Sedge fen mires are very rich in birdlife, and in biodiversity in general. Numerous wader species such as the Common Snipe, Great Snipe, Black-tailed Godwit, Common Redshank, and Eurasian Curlew; rails such as the Spotted Crake, Corncrake, Water Rail, and Common Moorhen; harriers; the Short-eared Owl, Black Grouse, Common Crane; and many passerines such as the Meadow Pipit, Sedge, Savi's and Grasshopper Warblers, Whinchat, Bluethroat, and Reed Bunting breed here, often at their highest densities. Species number and total abundance of breeding birds in intact fen mires can be higher than in near-natural beech forests of the same region, and ten times higher than in open arable land. Anyone who has experienced this fascinating rich birdlife during a sunset or sunrise in May, for instance in the famous Biebrza Marshes of Poland, will never forget it. He or she will be overwhelmed, like the German ornithologist Erich Hesse, who described these magnificent landscapes from Germany northwest of Berlin in the early 20th century in the Journal of Ornithology (1911-1914). After large-scale drainage and land reclamation campaigns, nothing of this fascinating world remains there...

The Aquatic Warbler stands for this habitat, and it shares the disastrous fate of the fen mires during the past century. For more than two decades, the Aquatic Warbler has been in focus of the work of BirdLife International in Europe. In 1993, BirdLife held the first international workshop on the Aquatic Warbler in Ruda Milicka in Poland and drafted the first Species Action Plan. However, at that time only the Polish, Hungarian, and tiny German populations were known. The knowledge about breeding occurrence east of the Polish borders was more or less zero. The same was true for the African wintering grounds. After the discovery of the major part of the global population in 1995 and 1996 by Martin Flade and co-workers, BirdLife became increasingly engaged in Aquatic Warbler conservation work. As the UK BirdLife partner, the Royal Society for Protection of Birds (RSPB) initially took on the leading role within the BirdLife family and supported, also with funding from the German Michael Otto Foundation, the foundation of a strong BirdLife partner in Belarus (APB, 1997/98) and the foundation of the BirdLife International Aquatic Warbler Conservation Team (AWCT) in 2008 at Brodowin (Germany). In 2008, the BirdLife AWCT drafted the second Species Action Plan and initiated the Memorandum of Understanding for the Conservation of the Aquatic Warbler under the Convention on the Conservation of Migratory Species of Wild Animals (CMS, or Bonn Convention), which was signed in Minsk (Belarus) in 2003. Last but not least, the RSPB facilitated and supported the application and implementation of two big EU-LIFE projects in Poland as well as big conservation projects in Belarus, also supported by the UK Darwin Initiative, the United Nations Development Programme, the Global Environmental Facility and others. The RSPB was also engaged in conservation-oriented research on the Aquatic Warbler, especially in order to identify the recent wintering grounds of the species by means of an analysis of historical records, an analysis of remote sensing data, and studies on stable isotopes in Aquatic Warbler feathers.

Recently, the German BirdLife partner NABU has taken over the leadership role within the BirdLife family from the RSPB. Since Germany is still within the current

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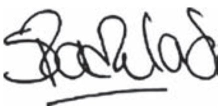
breeding range of Aquatic Warbler, and the input into Aquatic Warbler conservation work from the German side has always been strong, the new active role of NABU is an ideal solution. Fortunately, the EU-LIFE project on the conservation of the Lesser Spotted Eagle, Corncrake and Aquatic Warbler in the German Schorfheide-Chorin Biosphere Reserve supported the publication of this Aquatic Warbler conservation handbook – a true monument to enthusiastic engagement, international cooperation, decades of intense research, and conservation management experience of the BirdLife network and its cooperation with other renowned experts, international agencies, and donors.

I am convinced that this new handbook will provide a comprehensive basis for successful conservation and project work in order to save this globally threatened species, and to protect and restore its unique habitat.



Patricia Zurita
Chief Executive
BirdLife International

The Aquatic Warbler as a Natura 2000 & LIFE focus species

In May 2015 I had the wonderful experience of seeing a singing male Aquatic Warbler on its breeding grounds at the Curonian Spit in Lithuania. As this was the occasion of an international seminar on the Aquatic Warbler, I was also very fortunate to meet many of the conservationists and scientists that are committed to improving the status of this migratory species and to learn about the excellent collaboration they have developed over the past two decades, much of it supported by the European Union. They have an important story to tell and I am therefore delighted that this collective experience is brought together in this new handbook. It will be an essential resource for further action to improve the status of the Aquatic Warbler and its habitats in Europe and beyond.

As a breeding bird the Aquatic Warbler is endemic to continental Europe, with major populations in Poland and adjacent parts of Lithuania, Belarus and Ukraine. Almost the entire global population passes through France and the Iberian Peninsula during autumn migration. Therefore, the EU has a major responsibility for its conservation. The species is listed in Annex I of the EU Birds Directive, which requires Member States to take special habitat conservation measures for it, including through designation of Special Protection Areas (SPAs). The species is also protected under the Bern Convention on European Wildlife as well as the Convention on Migratory Species (CMS).

Furthermore, the Aquatic Warbler is a true umbrella species, a representative of mesotrophic sedge fen mires, an endangered ecosystem that is very rich in birdlife and biodiversity. Once common and widespread in the European lowlands, this habitat type has become extremely rare and is now protected under the EU Habitats Directive, including through designation of Special Areas of Conservation (SACs). Therefore, action to conserve the Aquatic Warbler and its habitats, particularly in Natura 2000 network of protected areas, provides multiple benefits for nature.

Given its threat status the Aquatic Warbler is a priority species for funding under the EU LIFE programme. One of the first ever LIFE projects, back in 1993, was on globally threatened birds in Europe. Led by BirdLife International it included the development of the first international Species Action Plan for the Aquatic Warbler. This now exists in its third updated version from 2016 as a joint action plan for the EU and the CMS. As with the earlier versions, it provides a strategic framework to help targeted conservation action and investment for the Aquatic Warbler and its habitats.

And the EU LIFE programme has been a major catalyst for a lot of practical conservation action for this species over the past two decades, especially focused on Natura 2000 areas. Within the breeding range, the Polish-German LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (2005-2011) was the first to undertake large-scale habitat restoration, developing and testing sound habitat management methods, including new types of agricultural machinery, in West-Pomerania and the Biebrza National Park. A new agri-environmental scheme (AES) was developed, perfectly adapted to the needs of this threatened warbler, which has resulted in strong recovery of populations in East-Poland. Only the tiny Pomeranian population, the last remnant of a once large population still present in the early 20th century, remains a cause for concern, despite substantial improvements to its habitats.

Building on the success of the Polish-German collaboration, the Baltic Aquatic Warbler LIFE Project 'Securing sustainable farming to ensure conservation of globally threatened bird species in agrarian landscape' (2010-2015) has successfully transferred this ex-perience to Lithuania and Latvia, further developing it to meet regional conditions. This has likewise led to a prompt recovery of the Lithuanian population. Experience from the Polish-German project has been further developed and applied to the Polish project on 'Facilitating Aquatic Warbler habitat management through sustainable systems of biomass use' (2010-2015).

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Inspired by these successes, the LIFE project 'Improvement of the Breeding and Foraging Habitats of Lesser-Spotted Eagle, Corncrake and Aquatic Warbler in the SPA Schorfheide-Chorin' (2011-2019) is focusing on the restoration of spring and percolation mires in the vicinity of the last Pomeranian breeding sites of the Aquatic Warbler. The Lithuanian-Belarusian LIFE Project 'Stepping stones towards ensuring long-term favourable conservation status of Aquatic warbler in Lithuania' (MagniDucatusAcrola; 2016-2023) is working to improve habitats and to link, through creating stepping stones, the population at the Curonian Lagoon and the global core breeding sites in Belarus. The latter will serve as a source population for a first pilot translocation project to replenish the population at restored Lithuanian sites. This exciting novel approach has high relevance also for abandoned former Aquatic Warbler sites in other European regions such as West-Poland, Germany, and Hungary.

The non-breeding sites have not been neglected. The Spanish LIFE Project 'Conservation of the Aquatic Warbler in the ZEPA La Nava-Campos' (2002-2006) was the first to develop and test management measures at important stopover sites in Southwest-Europe. This was followed by the LIFE project 'Conservation of the Aquatic Warbler in Brittany' (2004-2009) in France. A new LIFE project 'Habitat restoration for the Spring and Autumn migration of the Aquatic Warbler in the Iberian Peninsula', launched in 2017, aims to transfer the experience of the former more localised projects to several regions across the Iberian peninsula.

All of these initiatives have required careful organisation and collaboration. I would like to pay tribute to the BirdLife International Aquatic Warbler Conservation Team (AWCT) that, starting in 1998, unified and coordinated action in Europe and since 2007 also in Africa. The activities and projects have been discussed and developed within this network, including the 'Memorandum of Understanding concerning conservation measures for the Aquatic Warbler' under the CMS, which was concluded in Minsk in 2003.

All of these scientific and conservation projects and experiences of more than two decades are now captured in this outstanding Aquatic Warbler Conservation Handbook. Written by more than 30 authors, it represents the 'state of the art' on conservation and habitat restoration for the Aquatic Warbler in 15 countries, providing a unique and comprehensive summary of available knowledge. Great credit is due to the two editors, Franziska Tanneberger from Germany and Justyna Kubacka from Poland, for collecting and editing the different contributions, applying a clear and consistent approach. I am very glad that it was possible to realise this vision, which does justice to all the work achieved under the different LIFE projects in Natura 2000 and elsewhere. I am confident that this book will successfully support future conservation initiatives as well as act as a catalyst for conservation research to fill the remaining gaps in knowledge.

Dr Micheal O'Briain
Deputy Head of Nature Unit & Senior Expert
DG Environment, European Commission

A little brown bird that changed our life

When we, a small group of six enthusiastic young Germans, took the train to Minsk in May of 1995, we could not envisage how this trip would shape biographies, careers, friendships, and even change vast landscapes over the next two decades. We did not know the Belarusian colleagues waiting for us at the Minsk's main train station, we did not know the country or the landscapes over there, and we had no idea whether there would be any chance of finding Aquatic Warblers in the Prypiac Marshes, or even whether there would be any small patches of sedge fen left. However, we arrived to find enthusiastic, engaged, and competent people, outstanding hospitality and – thousands of Aquatic Warblers within tens of thousands of hectares of fen mires. On the other hand, however, we also saw huge drainage and land reclamation machinery, and big caterpillar-tracked vehicles in full action in the Zvaniec Mire.

Only a few years later, the drainage of the last Belarusian fen mires was stopped, large protected areas were established, a strong nature conservation NGO was founded in Belarus, and the BirdLife International Aquatic Warbler Conservation Team was founded at Brodowin in 1998. A new Species Action Plan was compiled for the EU, a big conference on mires and floodplains in the Polesie region was held, and we found ourselves preparing an international agreement for the protection of the Aquatic Warbler under the Bonn Convention, which was signed in 2003.

We went to Siberia for three amazing expeditions in 1999-2001 and, contrary to our expectations, found less than a dozen singing Aquatic Warblers lost somewhere in the endless mire landscapes between the Ural Mountains and the Ob River. But the best thing was that formerly unknown foreigners became reliable partners and trustable friends, working towards the same target across a range of professions, countries, even continents, and political systems.

Big projects for the Aquatic Warbler and fen mires were started in Belarus, Poland, Lithuania, and Ukraine; young scientists were employed to perform field work and data analysis; high level research projects were initiated on breeding ecology, genetics, stable isotopes, and much more. The international community became increasingly aware of the Aquatic Warbler as a globally threatened flagship species, as well as the importance of fen mires for biodiversity and climate change mitigation. A series of EU-LIFE projects funded by the EU Commission and designated to the conservation of the Aquatic Warbler and its habitats was launched.

The same kind of pioneering feeling that we experienced in 1995 in the Belarusian Prypiac Marshes and 1999 in the West-Siberian plains, overcame us again when we found ourselves in the vast marshes of the Senegal Delta in West-Africa in January 2007. We had no idea if and how we could find our little brown bird there. I will never forget the situation when colleagues from Belarus, Ukraine, Latvia, Lithuania, Hungary, Poland, Germany, France, Spain, Portugal, Senegal, Ghana, and Mauritania stood together in the vast marshes of the Senegal Delta, the strong desert wind 'Harmattan' blowing in their faces, realising and deeply understanding how the fate of the Aquatic Warbler is connecting Europe and Africa, the Polesie and the Sahel, linking the problems of mire conservation, climate change, carbon sequestration, desertification, and management of the declining fresh water resources in the Sahel, problems of growing hydro-agriculture and irrigation, economic north-south suppression, and endangered wetlands on the southern margin of the Sahara... Global change and global challenges in a nutshell.

And now, 23 years after our Prypiac expedition, 20 years after the foundation of the Aquatic Warbler Conservation Team, and eleven years after the discovery of the African wintering grounds, we are able to present a comprehensive summary of all the research and knowledge on the species, on mire restoration, habitat management, and project experiences of more than two decades of joint work in one influential book publication. It is thanks to Dr Franziska Tanneberger and Lars Lachmann, who initiated the first approach

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to creating such a handbook in 2010, in the course of the former Polish-German LIFE project, and thanks to Dr Franziska Tanneberger and Dr Justyna Kubacka, who picked up the work on the book in 2016 and led the project to its completion, having gathered all the experts again and updated and improved the former drafts, undertaking all the editorial work. This task was even more significant, as many things have developed and changed quickly in recent years. Several important chapters had to be completely rewritten due to recent new experiences and research results. Now here we are with the impressing results.

As always in the AWCT history, this book is result of a huge teamwork, joint contributions from more than 30 experts, full of enthusiasm about their joint mission. Huge thanks to all of them!

But we should also recall the work of some other supporters who are probably less visible in the book. The German Michael Otto Foundation for Environment has the distinction of being the first to support research and conservation projects in the politically isolated country of Belarus in the mid-1990s, and held the first big conferences on the importance and protection of wetlands in the Polesie region. Thanks to the engagement of Dr Norbert Schäffer, it was the Royal Society for the Protection of Birds that was the first big conservation organisation to become involved in and to support Aquatic Warbler research and conservation projects in Belarus, Poland, and the neighbouring countries. The RSPB also continuously funded the AWCT's work, as well as the position of CMS Aquatic Warbler Conservation Officer, and brought the first Polish-German LIFE project forward, allowing Lars Lachmann to act as the project manager.

It was a stroke of luck that we came in early contact with the famous mire ecologists from Greifswald University around Prof. Dr Hans Joosten and Prof. Dr Michael Succow, the International Mire Conservation Group (IMCG), and the newly founded Greifswald Mire Centre (GMC), a partnership of Greifswald University, Michael Succow Foundation, and DUENE e.V. The experts there contributed their vast knowledge and experience on mire ecology and restoration, and supervised numerous master and PhD students working on the Aquatic Warbler and its habitats. They also opened our eyes to the importance of peatlands for climate protection.

So I would like to conclude with offering my sincere gratitude to all these supporters, but primarily to Franziska and Justyna for their excellent editing, and to all the contributors for writing this outstanding book as a true milestone of the Aquatic Warbler conservation work. I am convinced that it will become an invaluable tool for nature conservation in many European and African countries.

Dr Martin Flade
Chairman of the Aquatic Warbler
Conservation Team

1 Introduction

FRANZISKA TANNEBERGER, LARS LACHMANN & JUSTYNA KUBACKA

Information about Aquatic Warbler conservation is distributed over a large number of scientific articles, reports, and informal documents, which are not easily accessible and are hard to summarise for an ordinary person interested in Aquatic Warbler conservation. The aim of the handbook is to summarise this knowledge, which has grown so much in recent years, illustrate it with practical examples, and make it accessible.

The main target group of this handbook are conservationists (such as site managers), political decision makers from competent authorities (such as staff of national environment ministries or regional conservation units), and local stakeholders (such as landowners, land managers, water authorities, or mayors), as well as generally interested naturalists and scientists.

This book is meant to collate and summarise the existing scientific and practical knowledge and experience relevant for the conservation of the Aquatic Warbler in its breeding grounds. Aspects related to migration and wintering are covered more generally in one summarising chapter each.

The structure of the book more or less follows the logic of a species action plan. The long Chapter 2 provides general information about the ecology of the species and covers species characteristics, distribution and numbers, habitat requirements, food and foraging, breeding, voice and song behaviour, population dynamics, genetics, migration, and wintering. Chapter 3 summarises threats and limiting factors and is followed by another long chapter (Chapter 4) with information on habitat management - water management, bush and shrub removal, mowing, grazing, and controlled burning. The book ends with recommended research and monitoring activities (Chapter 6) and communication (Chapter 7). All relevant references are presented at the very end of the book.

2 Ecology

2.1 Species portrait

FRANZISKA TANNEBERGER

The Aquatic Warbler (*Acrocephalus paludicola* Vieillot 1817) is a small (average weight c. 12 g) passerine bird breeding mainly in fen mires of temperate Europe and wintering in wetlands with similarly structured vegetation in Western Africa south of the Sahara.

Description

The main field characteristics are the badger-like head pattern (a creamy crown stripe, separated by two clear dark stripes from two creamy stripes above the eyes) and the back pattern with strongly contrasting creamy and black longitudinal stripes (Schulze-Hagen 1991; **Fig. 2.1.1** and **2.1.2**). The species could most easily be confused with the similar, but much more common Sedge Warbler (*Acrocephalus schoenobaenus*). However, this species does not show a clear crown stripe (juveniles have a more vague yellow-buffish crown stripe) and has much less contrasting plumage on its back.

In contrast to all the other *Acrocephalus* species, the Aquatic Warbler has a breeding system that involves uniparental care by the female (see Chapter 2.5). The mating system is promiscuity and is characterised by intense sperm competition, with the majority of broods fathered by more than one male (Dyrcz et al. 2002: 78%). A rich food supply seems to be essential because the female feeds her (usually four to five) nestlings alone (Leisler & Catchpole 1992). Prey consists mainly of arthropods, with large temporal and site-specific differences in composition (see Chapter 2.4). The home ranges of males comprise 2-8 ha (on average 4.6 ha, N=5 males) and overlap widely, according to a study from the Biebrza Valley, Poland (Schulze-Hagen et al. 1999, Schaefer et al. 2000).

Plumage formation is completed at the age of 14 days (Wawrzyniak & Sohns 1977). First year and adult birds moult completely in the wintering sites and their moult is finished by the end of January (Tegetmeyer et al. 2012). During the breeding season, feathers are moulted partially (Wawrzyniak & Sohns 1977).

The sexes do not differ in plumage. During the breeding season they can be told apart, when held in the hand, by the cloacal protuberance in males and by the brood patch in females. Outside the breeding season, DNA analysis is the only way to tell the sex of a bird. The age of a bird during autumn migration can be estimated based on plumage colouration and different stages of wear of the feathers, with young (first year) birds having more orange and yellowish plumage and still showing fresh feathers and therefore a more contrasting colouration.

The Aquatic Warbler has the largest foot span within the genus *Acrocephalus*. In contrast to other species of the genus, it possesses clearly elongated central and outer toes and a shortened hind toe, as well as shorter claws. This appears to be an adaptation to moving around and climbing in grass-like vegetation, giving the species an intermediate position between *Acrocephalus* and *Locustella* warblers in terms of foot anatomy (Leisler 1975, Leisler 1981, Leisler et al. 1989).

The structure of Aquatic Warbler song is built by whistles and rattles (see Chapter 2.6). As in other *Acrocephalus* species, two types of song structures have evolved – long, complex and variable songs for mate attraction and simple, short songs for territorial defence (Catchpole & Leisler 1989). Songs are given from vegetation or in a short song flight.

Conservation status

The Aquatic Warbler was once widespread and numerous throughout Europe (Schulze-Hagen 1991, Cramp & Brooks 1992; see **Box 2.2.1**). For the federal state of Brandenburg in Germany, Hesse (1910) described the occurrence of '*Acrocephalus aquaticus*', as it was formerly named, as follows: 'Among the *Acrocephalus* species, it is the true fen warbler [...]. What in particular characterises the Aquatic Warbler is its commonness [...]; it occurs all over the vast fen mires... and here, we have at times particularly large aggregations [...]' (own translation). For the region south of Szczecin (Northwest-Poland), Hübner (1908) describes the

◄ **Fig. 2.1.1**
Characteristics of Aquatic Warbler plumage, showing an adult bird (A) and a young bird (B), and for comparison a young (C) and an adult (D) Sedge Warbler.
Drawing by Alban Larousse.

2.1

Box 2.1.1
Why should we protect the Aquatic Warbler?

ŽYMANTAS MORKVĖNAS

Aquatic Warbler is Europe's rarest passerine bird – this scientific fact is often provided as argument to justify its need for conservation. However, conservation motivation is primarily driven by values, while science is not a value by itself. Therefore, scientific facts shall be better used to back up the arguments, but not to replace them.

There can be many reasons to protect the Aquatic Warbler, and their relevance depends on individual systems of values. Understanding these different points of view is vital in framing conservation motivation to a specific audience. More biocentric-oriented people (stressing human co-existence with nature) will justify conservation based on intrinsic values – the Aquatic Warbler is seen as a value by itself, and humans shall respect it and seek for co-existence. The fact that the Aquatic Warbler is the rarest passerine bird in continental Europe and the only, which is under a real threat to be eradicated from the planet, might trigger people driven by intrinsic values.

More anthropocentric-oriented people (stressing that humans are not part of nature and shall utilise nature for their own benefit) will justify its conservation based on instrumental values. For some people, especially farmers, the fact that Aquatic Warblers make land and certain management eligible for payments from agri-environmental measures is important. For others, the Aquatic Warbler's suitability as an umbrella species for a very specific habitat and associated ecosystem services may be decisive. Or potentially negative consequences from species extinction can be a motivation: all life forms on the earth are entangled into one complex system where each species plays a special role in maintaining the general balance of this network. Although we, humans, have not fully understood this system, there is evidence that the extinction of species may disturb this balance and cause largely unpredictable and unwelcome consequences.

Last but not least, people tend to agree on protecting species in which they recognise some (social) human features. For example, a farmer in the Lithuanian Nemunas Delta is motivated to protect the Aquatic Warbler as she recognises that 'Aquatic Warbler eyes are smiling'. Others are triggered when they learn that female Aquatic Warblers take care of their families alone, or get inspired when they know about the sexual life of Aquatic Warblers.

A first exchange on why we should protect the Aquatic Warbler, gathering personal opinions and motivation across the AWCT, was organised in November 2013 in Vilnius and Šilutė, Lithuania. The discussion was part of the EU LIFE project 'Baltic Aquatic Warbler' (2010-2015) and organised in the format of 'Café Scientifique': in an informal environment Aquatic Warbler experts and scientists met people who care for the environment. Statements based on rarity, on intrinsic values and on instrumental values were made: "This bird is simply incredibly rare. There are 20 times more African Elephants in the world than Aquatic Warblers." (Dr Norbert Schäffer). "I am from France. People are asking me why they should care about this bird. My answer is: We ►

species as 'exceptionally numerous'.

Today, the Aquatic Warbler is the rarest and one of the three globally threatened passerine birds of mainland Europe (see also **Box 2.1.1**). The species is classified at the global level as 'vulnerable' (Birdlife International 2015). The reasons for this classification are the recent catastrophic population decline and the very small current area of occupancy of less than 1,500 km^2 (see also Chapter 2.2). It is also included in Annex I of the EU Birds Directive (79/409/EEC), in Appendix II of the Bern Convention and in Appendix I of the Bonn Convention. Under the Bonn Convention, the 'International Memorandum of Understanding Concerning Conservation Measures for the Aquatic Warbler' was signed since 2003 by 16 out of 22 CMS-recognised range states, including all of the most important countries from the breeding, migration, and wintering range.

Umbrella species

The Aquatic Warbler is a highly stenotypic species. The major threat to the population and the reason for its dramatic decline has been habitat loss (see Chapter 3). Hence, conservation efforts have concentrated on protecting the remaining patches of breeding habitat. The Aquatic Warbler 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 (**Fig. 2.1.3**).

In reference to the fens near Berlin, Germany, Hesse (1910) describes beautifully the wide range of birds which share this habitat and its surroundings with the Aquatic Warbler: 'The vast fens impressed me deeply: What a richness in plant and animal life! And most admirable, the birds, for example on a warm May evening – let us just think of the most characteristic species: The cawing of terns, the screaming of Lapwings, the piping of Redshanks, the yodelling of Godwits, the bleating of snipes, the trumpeting of Cranes, the booming of Bitterns, the gobbling of Blackcocks, the whispering of Pipits, the whirring of *Locus-*

tella warblers, the rattling and whistling of Aquatic Warblers, the plain song of the Whinchat – moreover several skeins of flying ducks, a few heavy weight Bustards, Short-eared Owls crossing quartering their territories, and here and there harriers sculling gull-like through the air, and the vast endless realms lightened by the evening sun – what a wonderful piece of nature!' (translation by Franziska Tanneberger & Rob Field).

Among the species listed in the EU Birds Directive Annex I, 16 species often occur together with the Aquatic Warbler, e.g. Bittern (*Botaurus stellaris*), Marsh Harrier (*Circus aeruginosus*), Montagu's Harrier (*Circus pygargus*), Greater Spotted Eagle (*Clanga clanga*), Great Snipe (*Gallinago media*), Short-eared Owl (*Asio flammeus*), and Wood Sandpiper (*Tringa glareola*).

Aquatic Warbler breeding sites are not only important for animals, but also for habitat and plant conservation. They comprise at least eight habitat types from the EU Habitats Directive, including three priority types. Examples for especially valuable Aquatic Warbler breeding sites include:

- Biebrza Marshes comprise large areas of transition mires and quaking bogs (Habitats Directive Annex I Code 7140). In total, they host almost 1,000 species of vascular plants and a large number of moss species, many of them rare and protected, e.g. the Habitats Directive Annex II orchid *Liparis loeselii* and moss *Drepanocladus vernicosus*. With some 48,000 ha, this is the largest area of alkaline fens in Central and Western Europe with high diversity of fen types, including hydrologically well-preserved sites such as the Ławki Mire, the most important nesting area for the Aquatic Warbler in the EU;
- Chełm Marshes are the largest area of calcareous fens with *Cladium mariscus* (Habitats Directive Annex I Code 7210) in Poland;
- Zvaniec Mire in Belarus is Europe's largest mesotrophic fen mire (area c. 16,000 ha, remnant of a formerly huge fen mire drained only in the late 1980s), containing 67 protected vascular plant species, including 23 listed in the Red Data Book of the Republic of Belarus (BirdLife International 2017a);
- Žuvintas mire complex (6,847 ha) is the largest in Lithuania and consists of raised bogs (71%), transitional mires (17%), and fens (12%). In the territory of the Žuvintas Biosphere Reserve, 1,058 plant species were recorded. Aquatic Warblers occur on areas with Habitats Directive Annex I Code 7140 habitat (transition mires and quaking bogs);
- In Pomerania, the Rozwarowo Marshes hold the largest population of *Myrica gale* (Myrico-Salicetum auritae) in Northwest-Poland (Jurzyk 2004a, 2004b). This community is closely linked to the Aquatic Warbler breed-

Box 2.1.1 contd protect paintings, we protect churches, we protect castles. There is the same sense in preserving a Picasso painting and a Gothic church as it is for the Aquatic Warbler. It is our heritage. Natural heritage." (Raphaël Musseau). "Spending time on the Aquatic Warbler makes you friends internationally." (Jarosław Krogulec).

▲ **Fig. 2.1.2**
Male Aquatic Warbler (photo: M. Matysiak).

Fig. 2.1.3
Project poster of the EU LIFE project 'Baltic Aquatic Warbler' (2010-2015). The poster presents the main idea of Aquatic Warbler conservation – when we protect this rare bird, we also protect its living environment and its neighbours. The poster was produced in English, Lithuanian, and Latvian languages.

ing habitat. Also *Carex pulicaris* (threatened with extinction in Poland; Jurzyk & Wróbel 2003, Wróbel & Jurzyk 2004; Annex I of the Habitats Directive Code 6410) and the Habitats Directive Annex II species *Liparis loeselii* grow here. In the eastern part of the peatland, rare halophytes of the Triglochino-Glaucetum maritimae with abundant *Aster tripolium*, *Glaux maritima*, *Juncus gerardii*, *Plantago maritima*, and *Triglochin maritima* occur (Ciaciura & Stępień 1998). Lake Miedwie comprises calcareous *Caricion davallianae* vegetation (Habitats Directive Annex I-Code 7210) with threatened species such as *Cladium mariscus*, *Schoenus nigricans*, and *Carex buxbaumii* (Wołejko et al. 2007);

- Lower Oder Valley National Park, the last Aquatic Warbler breeding site in Germany, is one of the strongholds of *Cnidion* meadows in Germany (Burkart et al. 2004). The *Cnidion* meadows of the Oder Valley are species-rich plant communities and are listed in Annex I of the Habitats Directive (Code 6440). River corridor plants 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.

Therefore, conserving the Aquatic Warbler means much more than the protection of a single species. Protecting its unique fen mire breeding habitat brings equal benefits to a large number of, sometimes less prominent, species of animals or plants. Thinking of ecosystem services, protecting Aquatic Warbler habitat means even much more: carbon storage and sequestration, nutrient retention, groundwater storage, evapotranspiration cooling, flood protection, and many more provisioning, regulating, and cultural services (Joosten 2016a).


aquatic warbler
species do not go extinct alone
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2.2 World distribution, population, and trends

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Global distribution and numbers

Until fairly recently, the Aquatic Warbler bred in five countries in central and eastern Europe, and since 2014 it has bred only in four countries. A small outlying subpopulation was found in western Siberia (Russia), but could not be confirmed after 2000 and is probably extinct. The global population of the species is currently estimated at c. 11,000 singing males (s.m.; **Table 2.2.1**), with the largest national subpopulations in Belarus, Ukraine, and eastern Poland, together making up around 98% of the global population (**Table 2.2.1**, **Fig. 2.2.1**). Some 70-78% of the total population is concentrated in just four key sites: Zvaniec (2,200-4,400 s.m.) and Sporava (500-600) in Belarus, Biebrza Valley (c. 2,600) in Poland, and the Ukrainian Upper Prypiat (2,700-3,200; as of 2016), and the habitat is highly fragmented (**Fig. 2.2.2**, **2.2.3**). The remaining population is concentrated at ten important sites, with 100-500 s.m. each (**Fig. 2.2.3**): Nemunas Delta and Curonian Lagoon (Lithuania), Poleski National Park, Chełm Marshes (Poland), Dzikoje (Belarus), Middle Styr, Chornohuzka, Lake Bile/Pisochne, Lower Stokhid, Udai, and Supii (Ukraine). A further 20 sites exist with regular occurrences of more than ten singing males. Altogether, the European breeding occurrence of the species is currently restricted to c. 60 regularly occupied breeding sites, of which only 34 sites hold ten or more males. At three more sites in western Siberia, very small numbers of birds (1, 2-3, and 8 s.m.) were recorded in 2000.

The breeding distribution of the species during the past 20 years has encompassed a range from Germany in the West to western Siberia in the East, and from Latvia in the North to Hungary in the South. The

► Table 2.2.1
Global Aquatic Warbler population estimates and trends 2007-2017 (Belarus, Ukraine, Pomerania, Latvia) or 2007-2016 (other regions) by geographical and national subpopulations. The Polish subpopulation is split into eastern and western Poland, as it belongs to two separate geographical subpopulations. Figures in italics indicate low data quality; see text for an explanation of the available data and its quality. Trends have been assigned using the available 'best knowledge' data and expert judgement.

Country/region and population group	Mean population estimate (singing males)	Population trend, comments
Central European	*10,769*	decreasing/fluctuating
Belarus	4,120	decreasing
Ukraine	*3,653*	fluctuating, but data quality low
East-Poland	2,996	increasing
Lithuanian	110	fluctuating with recent increase
Lithuania	110	strong decline until 2013, increase afterwards
Latvia	0	last breeding season records 2000-2002
Hungarian	65	no bird recorded since 2011
Hungary	65	steep decline until 2010 to 15-18 s.m., no bird recorded since 2011
Pomeranian	30	declining
West-Poland	28	strong continuous decline since mid-1990s
Germany	2	strong decline documented since early 19th century, 0-10 s.m. 2007-10, 3 s.m. in 2010, 3 s.m. in 2012, 1 s.m. in 2013, absent since 2014
Siberian	*0-500*	unknown
Russia (western Siberia)	*0-500*	last breeding season records from 2000 (western Siberia), possibly now extinct
Global population	*10,974*	stable/fluctuating but small geographical subpopulations all declining

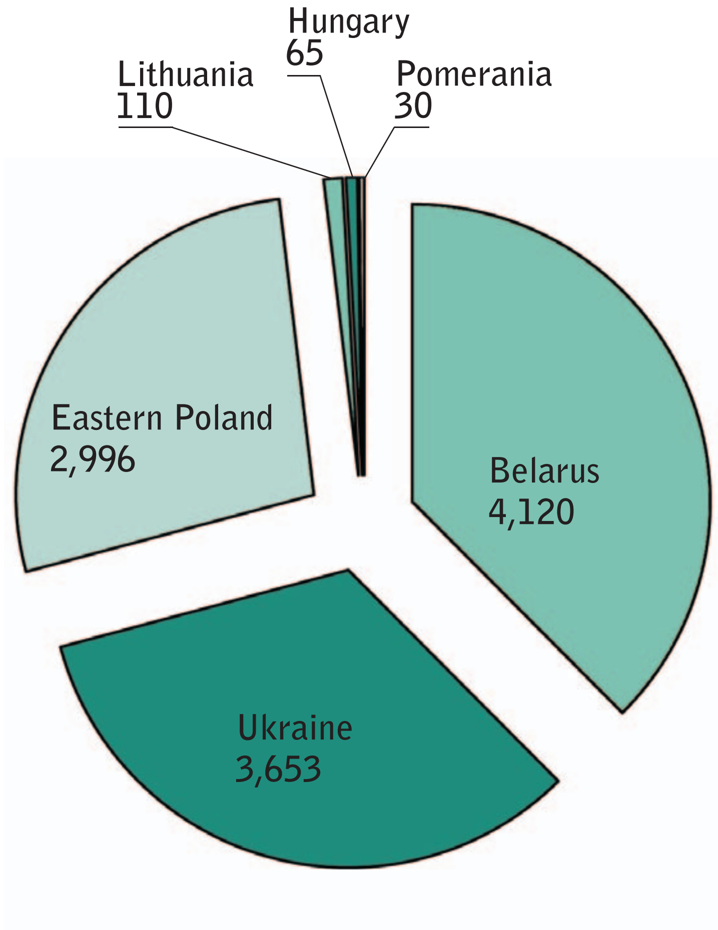
range has now further contracted to an area from Northwest-Poland in the West to central Ukraine in the East, and from the Curonian Lagoon in the North to West-Ukraine in the South. In stark contrast to this, all of the species' currently occupied breeding areas (known as the 'area of occupancy', AOO) amount to just 382 km^2 according to calculations by BirdLife International and the Aquatic Warbler Conservation Team (AWCT) in 2013. This extremely small area of occupancy is today the main reason why the species is classified as 'vulnerable' on the list of globally threatened species, as it is considerably lower than the classification threshold of 2,000 km^2 (IUCN 2012; see Chapter 2.1). The area of potentially suitable and restorable habitat in the occupied breeding sites (excluding western Siberia) is currently estimated at about 3,822 km^2, but, as the comparison with the AOO shows, only a small part of it is currently suitable and occupied (see also Chapter 2.3). Beyond this, a larger area of potentially suitable and restorable habitat exists in other sites that do not currently hold any breeding Aquatic Warblers (see Chapter 4.7).

▼ **Fig. 2.2.2**

(left page) Distribution of all known occupied Aquatic Warbler breeding sites in 2007-2016. Outside the area depicted on this map, additional breeding sites only existed in western Siberia until 2000, where a very small subpopulation may still exist. The map highlights the extremely fragmented breeding distribution of the species. 1 – Zvaniec, 2 – Sporava, 3 – Dzikoje, 4 – Upper Prypiat, 5 – Desna-Dnipro group, 6 – Biebrza Marshes, 7 – Poleski National Park, 8 – Chełm Marshes, 9 – Pomerania, 10 – Nemunas Delta, and 11 – Hortobágy National Park.

▼ **Fig. 2.2.3**

(right page) Numbers of Aquatic Warblers breeding in the sites occupied in 2007-2016. The circle size represents the number of singing males in each site. In some cases (e.g. the Biebrza Valley, northeastern Poland), a site consists of several adjacent subsites within a shared surrounding wetland area. The map highlights the extreme concentration of birds in only a handful of sites in the border region of Poland, Belarus, and Ukraine.

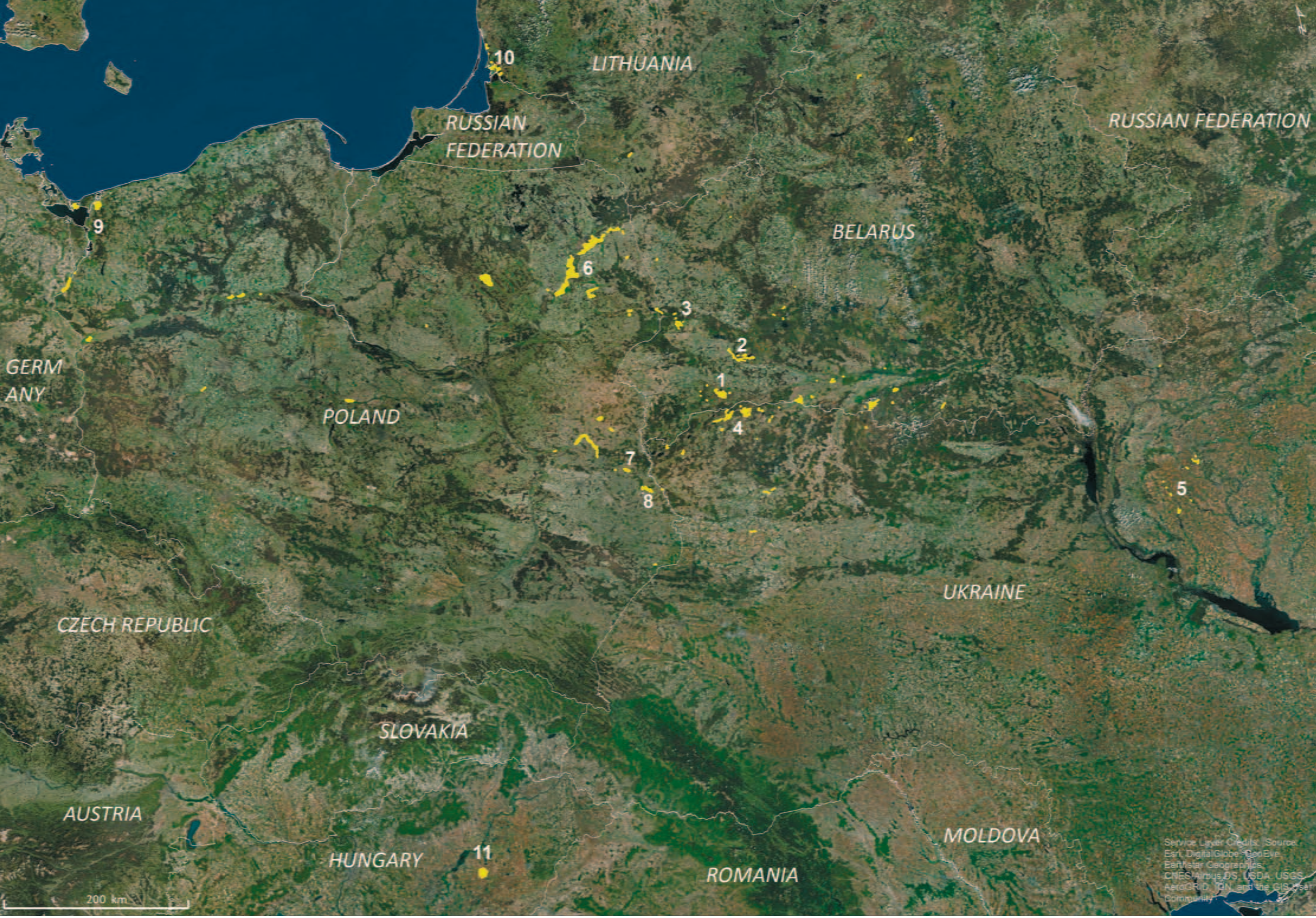


▲ **Fig. 2.2.1**

Average global estimates of the Aquatic Warbler population (singing males) in 2007-2017 (Belarus, Ukraine, Pomerania, Latvia) or 2007-2016 (other regions) by geographical subpopulations. The Belarusian, Ukrainian, and eastern Polish subpopulations together make up the central European subpopulation. The Pomeranian subpopulation straddles Germany and western Poland.

Considering the geographical isolation of subpopulations, the following biogeographic subpopulations – regarded as separate conservation units – can be identified:

1. a central European core subpopulation, including Belarus, eastern Poland and Northwest-Ukraine;
2. a central Ukrainian subpopulation, east of the Dnipro river;
3. a Lithuanian subpopulation (probably connected with the central European population through scattered small subpopulations in southeastern Lithuania and northern Belarus);
4. a geographically isolated Hungarian subpopulation (with no birds recorded since 2011);
5. a geographically isolated Pomeranian subpopulation in Northwest-Poland and Germany;
6. a West-Siberian subpopulation, which is isolated from the core population by a 4,000 km distance, with no records after 2000.



LITHUANIA
RUSSIAN FEDERATION
RUSSIAN FEDERATION
BELARUS
GERMANY
POLAND
UKRAINE
CZECH REPUBLIC
SLOVAKIA
AUSTRIA
HUNGARY
ROMANIA
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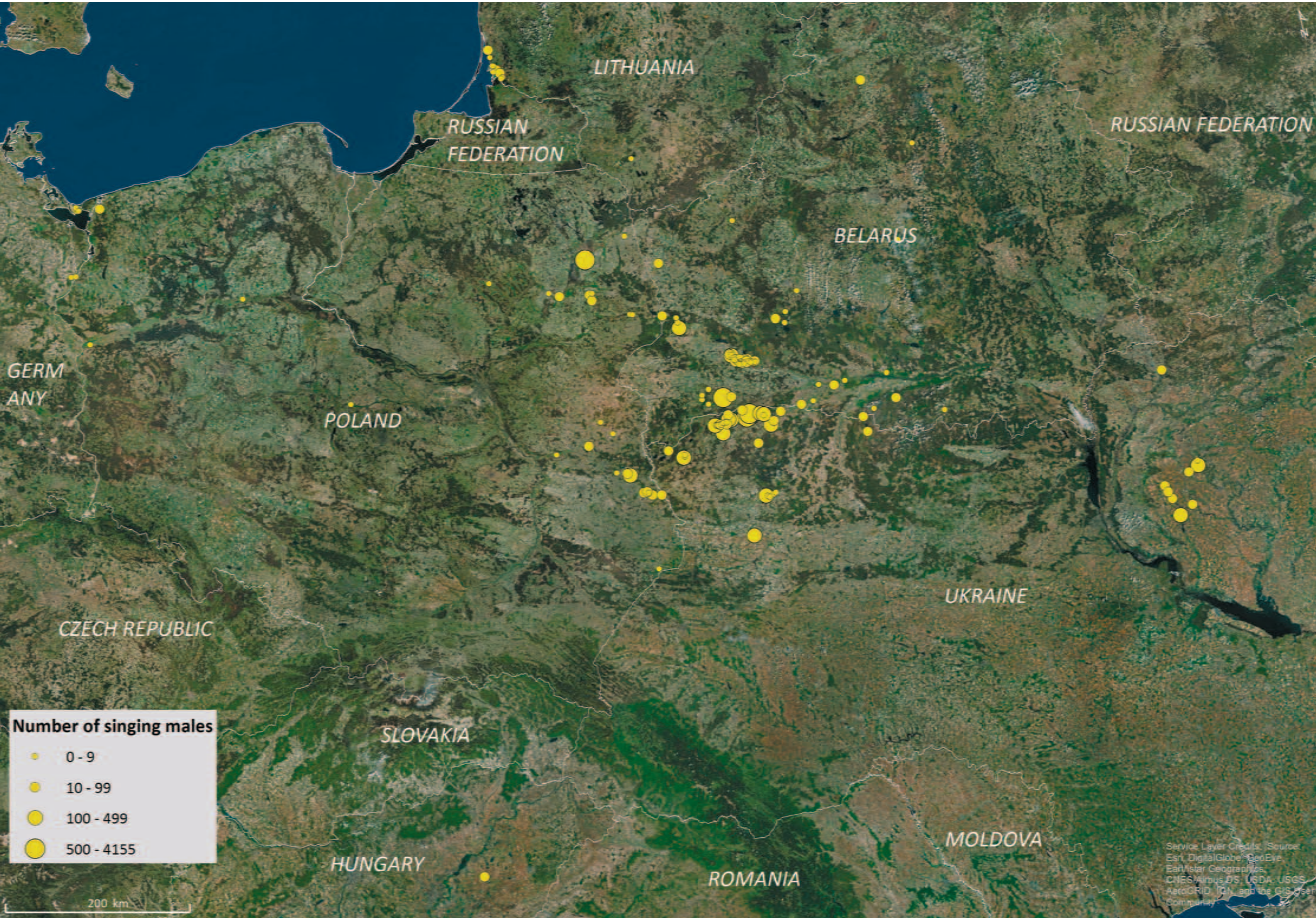
9
10
11
200 km


LITHUANIA
RUSSIAN FEDERATION
RUSSIAN
FEDERATION
BELARUS
GERM
ANY
POLAND
UKRAINE
CZECH REPUBLIC
SLOVAKIA
MOLDOVA
HUNGARY
ROMANIA
Number of singing males
0 - 9
10 - 99
100 - 499
500 - 4155
200 km

2.2

Box 2.2.1
Historical distribution

FRANZISKA TANNEBERGER & JOCHEN BELLEBAUM

The Aquatic Warbler was once widespread and numerous in many European countries (Schulze-Hagen 1991, Cramp & Brooks 1992; see Chapter 2.1). In primeval landscapes without human impact, the species probably occurred in mesotrophic or slightly eutrophic fen mires that remain treeless because of their permanently high water level and the limited weight carrying capacity of the loose, water saturated peats. Namely, these are 'percolation mires', which are found in landscapes where the water supply is large and evenly distributed over the year. As a result, the water table in the mire is almost constant relative to the surface. Dead plant material reaches the permanently waterlogged zone quickly and is subject to rapid aerobic decay only for a short time (Joosten et al. 2017). Consequently, the peat remains weakly decomposed and elastic (Succow 1982). Because of the large pores and the related high hydraulic conductivity, high water flow occurs over a substantial depth of the peat body (Wassen & Joosten 1996, Sirin et al. 1997, 1998, Schipper et al. 2007). Young percolation mires are sensitive to water table fluctuations but as the peat layer grows, these fluctuations are increasingly compensated by mire surface oscillation ('Mooratmung'). The peat's ability to oscillate makes conditions for peat formation at the surface increasingly stable (Michaelis & Joosten 2007). Before drainage, percolation mires were the prevailing type of mire in large parts of the Nemoral-submeridional fen region (VII in **Fig. 2.2.4**) and the Continental fen and bog region (VI in **Fig. 2.2.4**) (Moen et al. 2017).

Historical records of Aquatic Warblers have been compiled for several western and central countries of the former distribution range (e.g. the Netherlands, Germany, and Poland; see **Fig. 2.2.5**). The historical occurrence is closely related to peatland distribution in the lowland, and a large part of the lowland fens has been inhabited by the species in the past. Important breeding concentrations with high densities were known in the large, contiguous fen areas, e.g. in Brandenburg (Northeast-Germany; see also Chapter 2.1), peripheral subpopulations (also with substantial numbers) occurred e.g. in the Dümmer area (Northwest-Germany), and there was an extended network of fens with suitable habitat inhabited by the species from the Netherlands in the West to Russia in the East (Schulze-Hagen 1991).

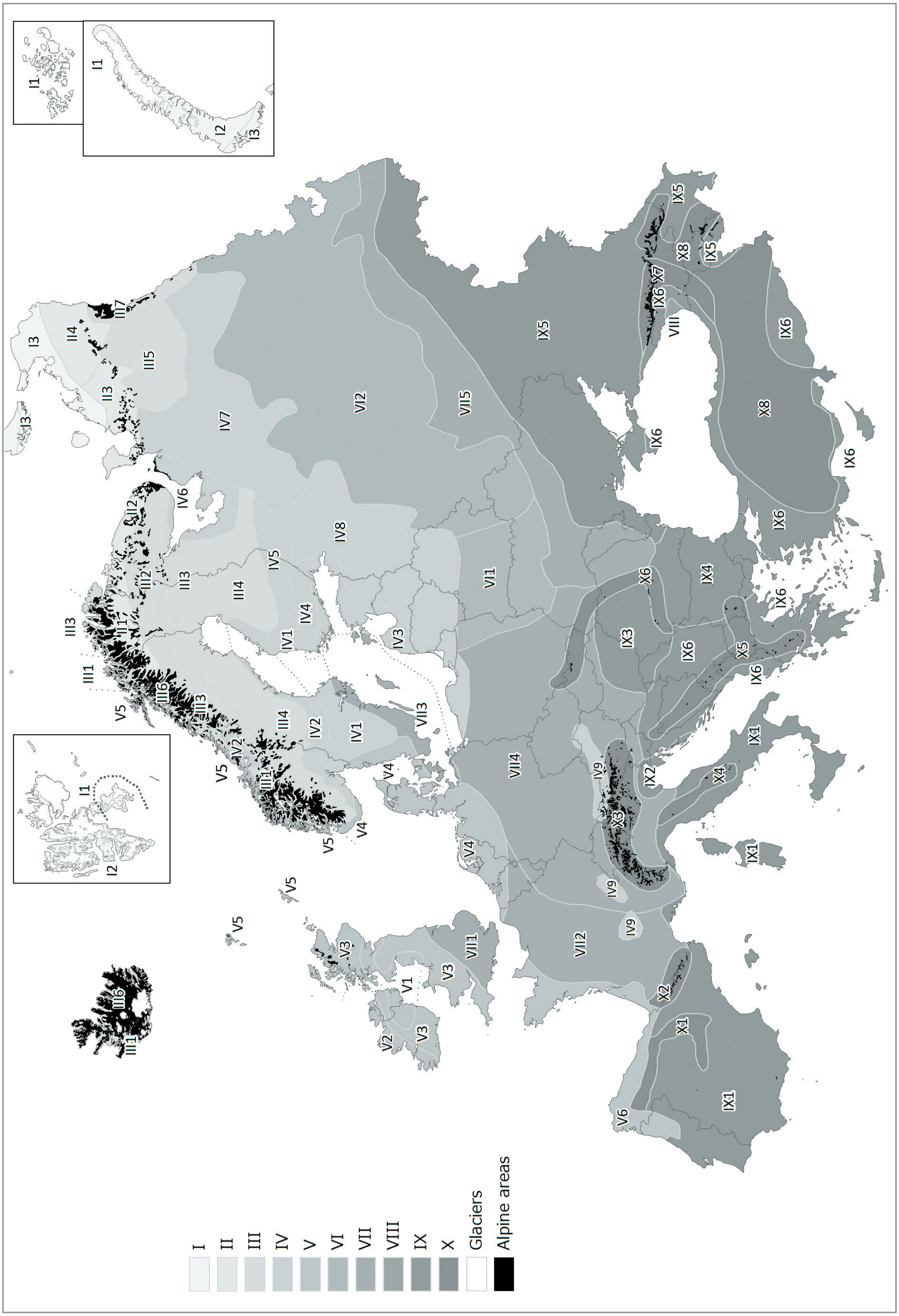
Population trends

As already outlined in Chapter 2.1, the global population of the Aquatic Warbler suffered a dramatic decline during the 20th century. The extent of the decline was estimated based on historic descriptions (**Box 2.2.1**), archival ringing data (Briedis & Keišs 2016), and the dramatic loss of suitable habitat through fen mire drainage (see also Chapter 3). It can also be deduced from the contraction of the breeding range, which once also included the Netherlands, Belgium, northern France, northern Italy, western Germany, and Austria (Cramp & Brooks 1992; see also Chapter 3). Recent estimates indicate that the world population decreased by around 95% between 1950 and 1980 (Briedis & Keišs 2016).

The species moved into the focus of the international conservation community only at the start of the 1990s. Since the first species workshop organised by BirdLife International in Poland in 1993, at a time when the occurrence of the Aquatic Warbler was completely unknown in Belarus and almost unknown in Ukraine, the species has been intensively studied. A large part of this research has been performed by a group of conservationists and scientists who, since 1998, have operated under the auspices of BirdLife International as the Aquatic Warbler Conservation Team (AWCT).

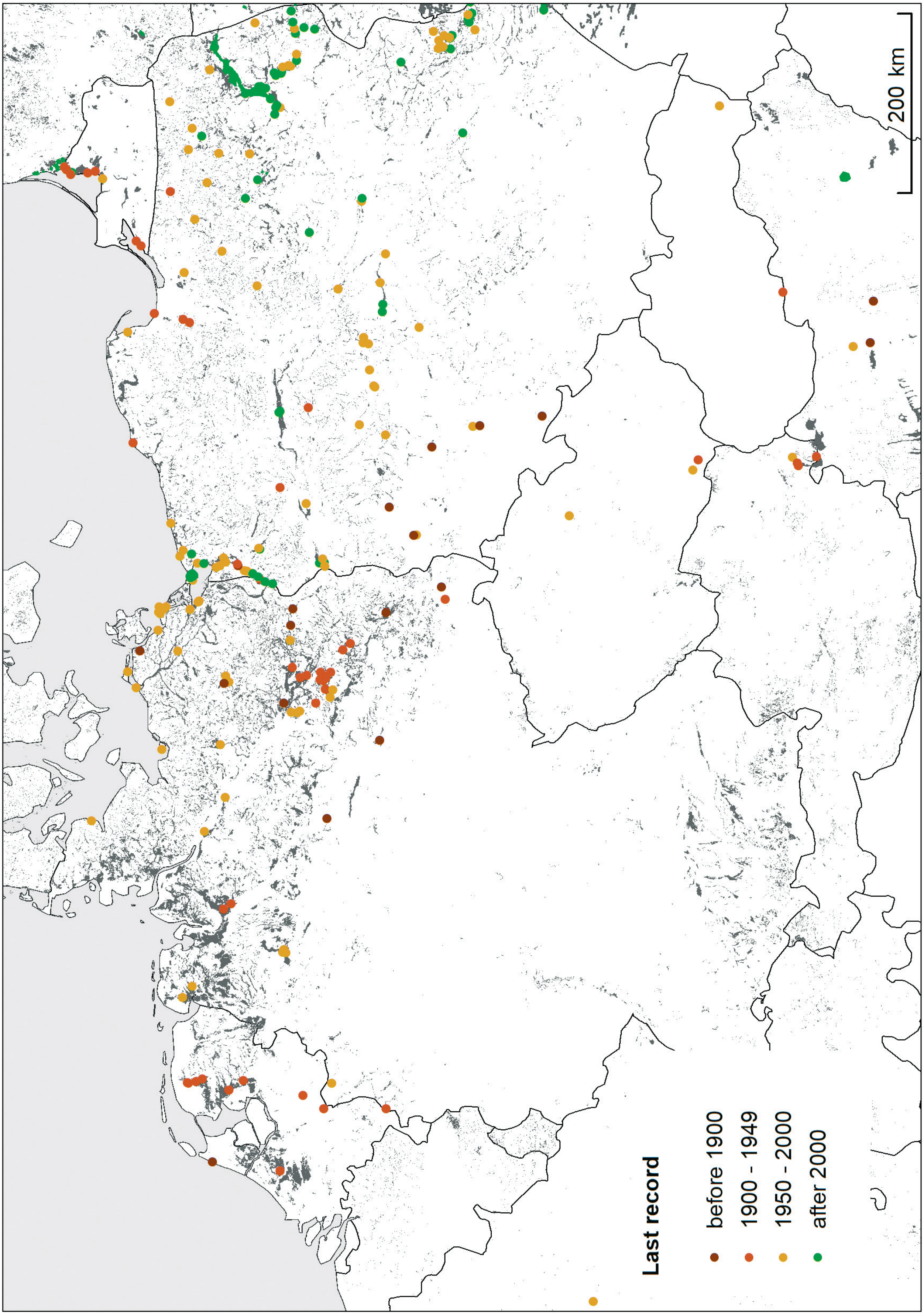
Thanks to the efforts of the AWCT, between 1995 and 2001 the extent of the current breeding range of the species was clarified. Since 1996, reasonable population estimates have been available for all the national subpopulations within Europe, most of them updated annually, while data from western Siberia are only available from a one-time effort to survey suitable habitats in the region during 1999-2002.

The very rapid global population decline ended after 1980, as shown by an analysis of historical ringing records collected between 1930 and 1997 (Briedis & Keišs 2016). Surveys carried out since 1996 have indicated stable or fluctuating numbers thereafter but depict a further strong contraction of the geographical range, mainly due to the loss of the Siberian



▲ **Fig. 2.2.4**
The mire regions and subregions of Europe. Modified after Moen et al. (2017).

2.2


200 km
Last record
before 1900
1900 - 1949
1950 - 2000
after 2000

and Hungarian subpopulations. The halt of the steep decline could be attributed to better knowledge about the species, allowing the initiation of the first targeted conservation activities, and to socio-economic changes in eastern Europe. At this time, large-scale drainage of the remaining fen mires in central and eastern Europe was halted for economic reasons, making it possible to arrange formal protection for a number of key sites in Belarus, Ukraine, and Poland. Soon afterwards, the first large-scale conservation projects targeting the improvement of the hydrological condition of three key Aquatic Warbler sites in Belarus were implemented (see Chapter 4.7).

For the period 2007-2016/2017, the average world population estimate is c. 11,000 s.m. (**Table 2.2.1**). Unfortunately, due to limitations of the dataset, which is based on different counting methods used in different countries and years, and the fact that some new sites were discovered throughout this period, especially in Ukraine, it is impossible to establish with high confidence a clear trend for the overall population. However, the available data suggest that the total population size has remained more or less stable. Major between-year fluctuations of recorded numbers are known from all the large breeding sites (e.g. Malashevich 2010, 2013, OTOP 2013, 2014, Grzywaczewski et al. 2015, Poluda et al. 2015, 2017, GIOŚ 2017), caused by annual differences in water levels or fire events, which additionally impede the establishment of reliable trends. Due to the fluctuations and the weaknesses of the counting methods used to date (Oppel et al. 2014), a slow underlying decline in population, caused by increased successional overgrowth of the remaining sites, may be going unnoticed.

While the global population appears to be stable, and there is a well-founded reason to assume that the initiated conservation efforts will eventually lead to an increase in the population, this is not the case for local subpopulations at smaller and peripheral breeding sites. The Pomeranian subpopulation in particular is currently experiencing a clear decline, and it is questionable whether the West-Siberian subpopulation still exists. The Hungarian subpopulation disappeared after a sharp decrease in 2010. Beyond the typical reasons for the species' decline (see Chapter 3), an additional problem for these more or less isolated subpopulations may be the absence of alternative sites nearby, which limits the opportunities to adjust to temporarily unfavourable conditions, and makes a small subpopulation even more vulnerable to extinction due to stochastic events, such as flood or fire.

Survey methods and data quality

Knowledge about the size of global and national populations, and their trends, is essential in order to assess the conservation status of a species and to set conservation priorities. However, a large-scale survey of the numbers and distribution of such an elusive passerine species as the Aquatic Warbler, which does not form pair bonds, does not occupy stable territories, and lives in poorly accessible peatlands, is a challenging task. On the other hand, the Aquatic Warbler also has some features that facilitate censuses: almost all males present in an area sing simultaneously around sunset, where weather conditions are suitable (Dyrcz & Zdunek 1993a); the population is concentrated in a very limited number of sites; and the species is a habitat specialist (see Chapter 2.3), making it relatively easy to identify potential breeding sites based on maps and aerial or satellite images. These features make it possible to conduct counts of a relatively large proportion of the population each year (see also Chapter 6).

To date, due to the very varied conditions in each of the breeding range countries in terms of the number and size of occupied breeding sites, as well as available organisational, personnel, and financial resources, it is clear that the methods and quality of national subpopulation surveys have differed considerably between the respective countries and over the years. However, a common standard has been to use singing

◄ **Fig. 2.2.5**
Aquatic Warbler breeding areas after 2000 and documented historical records (only for the Netherlands, Germany, Poland, the Czech Republic, Austria, Slovakia, Hungary, and the Kaliningrad oblast of the Russian Federation). Basic map: Peatland map of Europe (section, from Tanneberger et al. 2017b).

males as counting units, the density of which is correlated with nest and fledgling density (Kubacka et al. 2014), and to count males in the hours around sunset and in suitable weather conditions (no strong rain or wind), when singing activity is the greatest (Dyrcz & Zdunek 1993a; see Chapter 2.5). Surveys have taken the form of full counts (covering all the area of a breeding site) or sample counts, either along non-representative transects in the optimal habitat, or using a representative sampling design. In some cases, counts were repeated several times within a season, often with one count during the early season peak of egg-laying, and one during the late season peak; in others, only one count per year was performed. Recently, the reliability of the full surveys was questioned, due to their limited power to detect a change in population size, with repeated transect surveys being shown to be more precise (Oppel et al. 2014). Chapter 6 describes a concept of a unified monitoring methodology for Aquatic Warbler subpopulations in the breeding range, which would allow for more reliable number and trend analyses in the future. This will become increasingly important as a measure of conservation success.

National subpopulations and trends

Belarus

Annual Aquatic Warbler monitoring data have been collected in Belarus since 1996, only one year after the (re-)discovery of the species in the country. Currently, 15 regularly occupied breeding sites are known in Belarus, together holding 3,000-5,500 s.m., as estimated between 2010 and 2017 (Malashevich 2016 and U. Malashevich pers. comm.). With c. 35% of the world population (as of 2016; AWCT), Belarus is therefore the most important breeding country for the species. The single most important site nationwide and worldwide is the Zvaniec Mire, holding c. 25% of the world population and c. 75% of the national subpopulation. Together with two other important sites, Sporava and Dzikoje, it makes up 95% of the national subpopulation, while another five smaller but stable sites, and seven sub-optimal sites form the remaining 5% (**Fig. 2.2.2** and **2.2.3**).

The AOO is estimated at 13,865 ha (Malashevich 2016), while the total area of available apparently suitable habitat in the occupied sites is assumed to be 14,470 ha. Potentially suitable habitat in the occupied sites, i.e. including areas that could quite easily be restored to good habitat conditions, is estimated at around 35,000 ha for the seven most important sites, but may be as large as 70,000 ha when taking into account all 15 sites.

It is not easy to establish a national subpopulation trend, because of improvements in the monitoring methods used, which led to more accurate population estimates at the expense of comparability with earlier data. Between 1996 and 2005, regular monitoring concentrated on non-representative transects in the typical habitat at the three key sites in the country. This method documented strong fluctuations of local numbers due to flooding, drought, or fire, and was instrumental in the development and implementation of conservation measures, which by now have led to the stabilisation of the local breeding conditions, providing increasingly stable breeding numbers each year. Since 2006, a representative sampling design has been used for the largest site (Zvaniec), complemented with nearly full counts at the smaller sites. The changes in monitoring methods yielded more accurate population figures and also revealed that the previous national subpopulation estimates required a downward correction. Overall, since 2006, the Belarusian subpopulation appears to be decreasing (**Fig. 2.2.6a**), but a longer time series is necessary to verify this. The observed decrease in the area of suitable open habitat in the two key sites, Zvaniec and Sporava (and several others as well; see Chapter 3), together with the observed abandonment of small peripheral sites, may indicate a possible decline in the overall national subpopulation.

Ukraine

Mirroring the situation in Belarus, the Ukrainian breeding sites of the Aquatic Warbler were (re-)discovered in 1995 and 1996. Since 1996, annual monitoring data for the national subpopulation have been collected. Currently, 13 regularly occupied sites with a total of 31 sub-sites are known in Ukraine (Poluda et al. 2015, 2017; **Fig. 2.2.2** and **2.2.3**). Between 2000 and 2008, additional sites with significant Aquatic Warbler numbers were discovered, thus making it difficult to compare earlier national population figures with today's estimates.

The latest available data yielded a national subpopulation estimate of 3,067-3,555 s.m. (as of 2017; Poluda 2017), making up 28-32% of the world population (based on the estimate in **Table 2.2.1**). The national subpopulation is split into two groups, separated from each other by a gap of about 500 km: the larger Prypiat group is in the Northwest, occupying mainly sites along the upper Prypiat River, close to the Belarusian border (87% of the national subpopulation), and the smaller Desna-Dnipro group is in central Ukraine, east of Kiev (13%) (**Fig. 2.2.2**). One site in particular, the Ukrainian Upper Prypiat, is by far the largest in the country, contributing c. 68% of the national subpopulation, but there are more medium-sized sites with significant proportions of the national subpopulation than in Belarus.

The AOO is estimated at 7,900-8,000 ha (as of 2016; Poluda et al. 2017), while the total area of potentially suitable habitat at the occupied sites (including potential areas for restoration) may be larger than 20,000 ha.

Due to low resources available for monitoring, all monitoring data from Ukraine are derived from non-representative transect counts through the middle of each site, subsequently extrapolated to the apparently suitable area of habitat, and sometimes corrected for presumed lower densities at the peripheral parts of the site. Therefore, the data quality is unfortunately not sufficient to establish any significant trend. Only once, in 2016, due to the joint efforts of a larger AWCT counting expedition, 42% of the total suitable habitat area of occupied breeding sites was surveyed and counted (Poluda et al. 2017).

Until 2005, the national estimates had been increasing, also as a result of the discovery of new sites. Further increases reported since 2005 (**Fig. 2.2.6b**) may be either real increases, e.g. caused through favourable water conditions in most of the past years, or an artefact resulting from the monitoring design applied. For example, the centrally located sampling transects may be biased towards the higher density of birds in the centre of a mire, which features optimal conditions, unlike the edge, which could hold lower densities due to successional overgrowth. However, according to A. Poluda (pers. comm.), in the most recent estimates this effect was accounted for as far as possible, as only minimum estimates for such peripheral areas were used. When the monitoring design in the three large Belarusian sites was changed from the system still applied in Ukraine to a representative sampling design, significant downward corrections of the national estimates had to be made. In the future, improved counting methods should be able to clarify these questions also in Ukraine.

Eastern and central Poland

In eastern and central Poland, there are currently eleven regularly occupied Aquatic Warbler breeding sites, with the total of c. 3,881 s.m. in 2016, making up c. 34% of the world population (GIOŚ 2017). Its share of the world population is therefore similar to that of Belarus. The Polish subpopulation is dominated by a single large site, the Biebrza Valley in Northeast-Poland, which holds c. 24% of the world population (2014 data) and c. 80% of the national subpopulation. Only two other sites, the Poleski National Park and the Chełm Marshes, both located in Southeast-Poland, also hold more than 100 s.m. (**Fig. 2.2.2** and **2.2.3**).

The AOO in eastern and central Poland was estimated at 11,784 ha, while the area of potentially suitable habitat at the currently occupied sites, including areas that could quite easily be restored, is estimated at 30,000 ha.

National Aquatic Warbler monitoring data have been available from Poland since 1995-97, when the first full national count took place. Additional full national counts followed in 2003, 2009 and 2012, while in other years full counts were implemented only in selected sites or sub-sites. Aquatic Warbler monitoring in Poland has, thanks to a large number of available volunteers, so far always relied on full counts, even in the largest sites. This has resulted in excellent information about the distribution of birds across every site, and about the exact area of occupied habitat. However, it has been at the expense of not being able to implement the monitoring on an annual basis, and in most cases only one count per year, instead of the recommended two, was possible, thereby sacrificing better time-resolution and accuracy of the numbers derived from the counts. Therefore, a transition to a monitoring system based on annual representative sample counts at large sites and full counts on small sites, combined with national full counts every six years, is now being implemented (**Box 6.1** in Chapter 6).

Thanks to the full national counts conducted with identical methodology in 1995-97, 2003, 2009, and 2012, it is possible to establish with good confidence the overall stable population trend, with numbers oscillating around 3,000 s.m. (**Fig. 2.2.6c**). In addition, data obtained from transect counts carried out annually since 2011 show an increasing population trend (GIOŚ 2017), which is most likely to be caused by large scale management work implemented within the LIFE projects dedicated to the species (e.g. OTOP 2013, 2014) and the Polish agri-environmental scheme (see also Chapter 5 and **Box 5.4**).

Records of very small Aquatic Warbler subpopulations, with fewer than 50 s.m., have recently been reported from the Mazovia region (2 s.m. in 2012 in the Omulew and Płodownica river valley, and 2 s.m. in 2017 at the Narew river near the town of Łomża), and from central Poland, in the Ner and Bzura valleys (latest records in 2016 – 3 s.m.), the Noteć valley (latest record in 2017 – 6 s.m.), and at the Obra river near Kościan (2 s.m. in 2017). An analysis of long-term (1969-2013) census data of 38 small Aquatic Warbler subpopulations in four regions of Poland showed a steep decline in the size and number of the small central and western subpopulations, with some of them showing historical recolonisation events (Żmihorski et al. 2016). This emphasises how crucial it is to create stepping stone sites, to facilitate dispersal and connect small and prone to extinction local subpopulations with the core subpopulations in the East of Poland.

Pomerania

The Aquatic Warbler subpopulation currently breeding in northwestern Poland and northeastern Germany is being treated here as a separate subpopulation, as it is nowadays the most distant from the potential source subpopulations. Today, the Pomeranian subpopulation is on the brink of extinction, with only 8-15 s.m. in 2015-2017 (**Fig. 2.2.6d**). In 2005-2011, a single site, Rozwarowo (a commercially-used reedbed; see **Box 5.7**), held a small but stable subpopulation of 20-30 s.m., which formed the majority of the Pomeranian subpopulation. However, the Rozwarowo numbers have recently gone down by half.

The total AOO in this region is based on good data about the location of singing males over the past decades and spans a large area of 2,965 ha, which is due to the frequent re-location of birds between years. Depending on the management implemented, the potentially suitable (albeit not always actually suitable) habitat at the six breeding sites occupied in recent years amounts to 29,000 ha. The overall potentially suitable area in northwestern Poland and northeastern Germany is much larger, according to historical records widely available in this area, as well as recent modelling results (Frick et al. 2014).

Due to the low overall number of birds, all monitoring data for this region is based on full counts of whole sites. Scattered data confirm that the breeding subpopulation along the Oder/Odra river was large in the early 20th century, and probably declined over time with progressive habitat degradation (Robien 1920, Nowysz & Wesołowski 1972, Tanneberger et al. 2008). The area occupied by this subpopulation was first described by Dyrcz & Czeraszkiewicz (1993), though reliable estimates of its size exist only from 1993 onwards. Due to this limitation of data, the long-term trends from Żmihorski et al. (2016) for western and central Poland are not likely to be realistic. Since 2004, full counts in all the breeding sites in both countries have been implemented synchronously on the last weekend in May and the last weekend in June, in order to avoid double-counts due to individuals moving between sites. As part of a PhD project (Tanneberger 2008) and OTOP's 2005-2011 LIFE project, a database was developed that includes all the available counts from any of the breeding sites in the region, making this subpopulation the most comprehensively monitored Aquatic Warbler subpopulation, opening up opportunities for a more in-depth analysis of the population processes.

The Pomeranian subpopulation is critically endangered and has shown a steeply declining trend since 1997, a reduction from 262 to 8-12 s.m. in 2015 and 2016 (see **Fig. 2.2.6d**). A sign of hope are the large-scale habitat improvement works implemented as part of OTOP's LIFE project 2005-2011 'Conserving *Acrocephalus paludicola* in Poland and Germany' and the German habitat restoration project in the Lower Oder Valley National Park in 2011-2016 (Bellebaum & Tanneberger 2018), and other projects in recent years.

Lithuania

The birds in Lithuania are treated here as a separate subpopulation. In 2016, 247 s.m. were reported from three regularly occupied breeding sites in Lithuania (consisting of ten sub-sites).

The actual AOO is calculated as 1,800 ha, while the area of potentially suitable habitat is estimated at around 30,000 ha.

Aquatic Warblers were known to breed around the Nemunas Delta since the early 20th century (Tischler 1941). The first national subpopulation estimates were produced in 1996. The Lithuanian annual monitoring data represent full counts, complemented by the last available data from previous years for sites where full counts could not be implemented in a given year. Since 2000, most sites have been covered by full counts every year, yielding more reliable monitoring data. In 2004, a new site was included in the counts for the first time, which caused an unnatural peak in that year (**Fig. 2.2.6e**). Starting from 309 males in 2004, the Lithuanian subpopulation decreased to 52 males in 2013, and since then it has shown a distinct recovery, with 247 s.m. in 2016, and no significant change in 2017 (although only the first count in late May could be compared due to unsuitable weather conditions during the second count).

Hungary

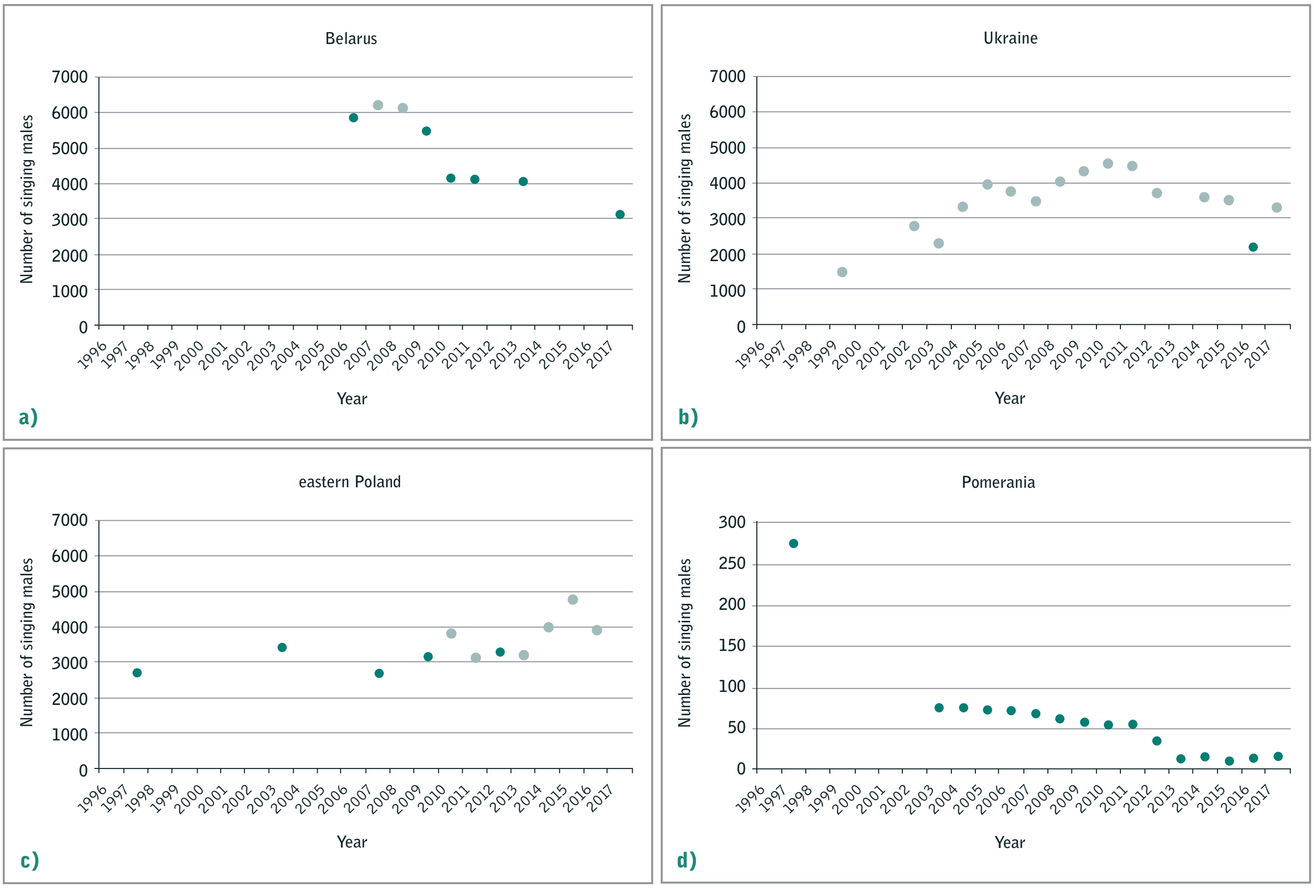
Aquatic Warblers have been absent from Hungary since 2011. The account given here is therefore historical. The Hungarian subpopulation is considered a separate geographical subpopulation due to the 600 km gap to the nearest other breeding site. Most likely, it did not exist before 1971, when the first birds were discovered to be breeding in the country (Kovacs & Végvári 1999). Since it exhibited extreme fluctuations and was located on the spring migration route of Ukrainian or Belarusian birds (see Chapter 2.9), it is plausible that the site was colonised by migrants coming back from Africa.

In Hungary, the breeding occurrence of the Aquatic Warbler was confined to the Hortobágy National Park. The AOO extended over 6,020 ha, while the potentially suitable area was estimated at 16,602 ha and remained under suitable land management and in favourable hydrological conditions. The development of the subpopulation was well documented since the first breeding record in 1971. In most of the years, the total subpopulation was covered by full counts, with gaps in the years 1973-1976, 1998-2000, and 2003-2004. An outstanding, nearly exponential increase, helped by a ban on pasturage at the site, peaked in 2001 with c. 700 males (**Fig. 2.2.6f**). However the subpopulation collapsed in 2002 to 331 males. Severe drought was observed in that year, and the fire that occurred after the breeding season caused the burning of 30% of Aquatic Warbler habitat. The subpopulation collapsed again in 2006 after a high and extended spring flood (which also did not make it possible to carry out a full count). A final collapse was observed after another spring flood in 2010 and since 2011 no male has been recorded, despite the habitat returning to favourable conditions. Thanks to the good location on the pre-nuptial migration route (see Chapter 2.9), the site might be re-colonised in the future, as long as the habitat is retained in a suitable state.

Russia and West-Siberia

Currently, despite an intensive search by the AWCT and collaborating ornithologists (field searches in the Ryazan, Moscow, Vladimir, and Perm regions in 1998, the Kaliningrad region in 2003, and the Smolensk, Pskov, and Tver regions in 2006), no breeding sites of the species are known from European Russia nor from the Kaliningrad region. Reports about small numbers of Aquatic Warblers in two sites in the Kaliningrad region around 2000 could not be confirmed by the AWCT in 2003.

The limited knowledge that is available about Aquatic Warblers in the huge area of fen mires in western Siberia is based on intensive AWCT field surveys in the years 1999 to 2001, during which only in 2000 three small and isolated subpopulations with 2-3, 1, and 8 s.m., respectively, were discovered at Lake Busly and in the Jarovskoe Mire in the northern Omsk region, and in the Tura floodplain mires north of Tyumen. This represents the only known breeding occurrence of the species in Russia after 1980. These three sites were no longer occupied in subsequent years until 2005, and among the studied sites in Siberia there are no sites where Aquatic Warbler occurrence could be confirmed for more than one year since 1960 (AWCT 1999). After these surveys, the AWCT estimated the total Siberian subpopulation very roughly at probably 50, but no more than 500 s.m.. Since only 11-12 males were counted in the field, this figure is only a guess. During further searches with limited coverage by local scientists, especially at the formerly occupied sites, after 2000 there were no records of the Aquatic Warbler in Siberia, despite huge areas of apparently suitable habitat. Therefore, it is unlikely that this subpopulation still exists.



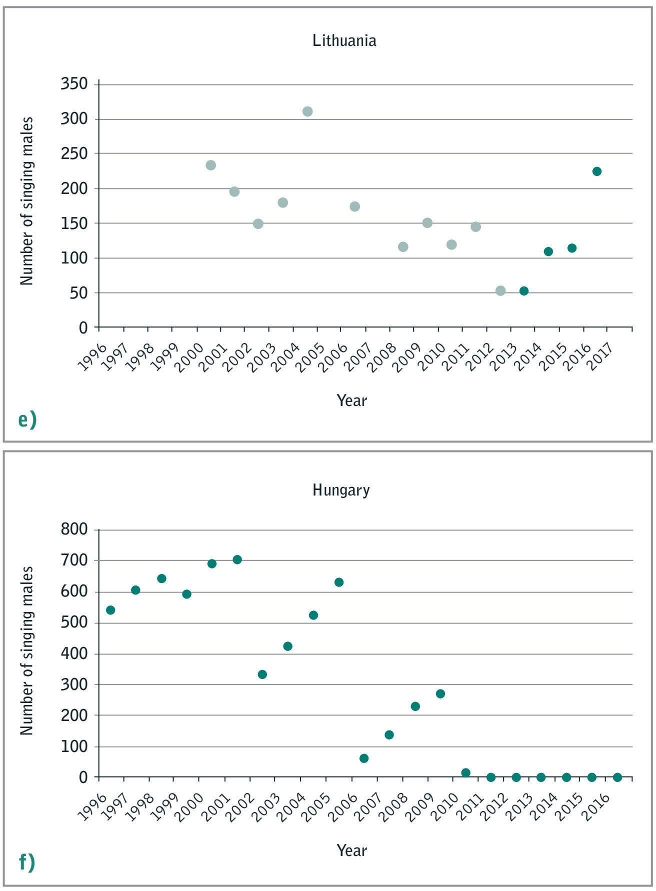


Fig. 2.2.6

The change of the Aquatic Warbler populations over time by each of the breeding range states. If several counts were performed within a breeding season, geometric means of minimum and maximum estimates are shown. Dark green circles are estimates of good quality and light green circles are estimates of low quality, relative to the overall data quality for a given state. a) For Belarus, dark green circles are comparatively good total estimates, but not based on full counts; light green circles are estimates or extrapolations from monitoring data obtained from sections of sites. b) For Ukraine, the dark green circle is based on a survey of c. 50% Aquatic Warbler habitat, carried out in an unusually dry year, when large areas were burned; light green circles are rough estimates or extrapolations based on (non-representative) monitoring transects in large sites and full counts in selected smaller sites. c) For eastern Poland, dark green circles represent nearly complete full counts, and light green circles are estimates or extrapolations from counts in selected sites (2010-2011) or from transect counts (2013-2016). d) For Pomerania, all the estimates are based on full counts carried out in June. e) For Lithuania, dark green circles represent complete censuses and are based on second brood counts (late June to early July); light green circles show the geometric means of minimum and maximum estimates, which are relatively good and available for all the sites from 2000 onwards. No estimates for 2005 and 2007 are depicted because in these years only a few smaller sites were counted. f) For Hungary, most estimates are based on full counts, with the exception of 1998-2000 and 2003-2004. Source: AWCT database.

2.3 Breeding habitat requirements

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► **Fig. 2.3.1**
Mesotrophic sedge fen with medium-sized sedges, flowering Bogbean *(Menyanthes trifoliata)* **and brownmosses at the Ławki Mire, Biebrza Valley, Poland** (photo: M. Flade).

► **Fig. 2.3.2**
Mesotrophic sedge fen near Kokoritsa at Sporava, Belarus (photo: A. Thiele).

► **Fig. 2.3.3**
Mesotrophic sedge fen and mineral islands at Zvaniec, Belarus (photo: A. Thiele).

► **Fig. 2.3.4**
Mesotrophic sedge fen at Dzikoje, Belarus (photo: M. Flade).

The Aquatic Warbler is a highly specialised *Acrocephalus* warbler that has evolved behavioural and morphological adaptations to allow both climbing (as the other *Acrocephalus* warblers) and running (as the *Locustella* warblers). Thus, it has been able to occupy an ecological niche in a habitat that is extreme for other *Acrocephalus* warblers: sedge fen mires and similarly structured wetland habitats with a vegetation height usually lower than 1 m, a water level at or (slightly) above soil surface and a very sparse or no shrub cover and no tree cover (Leisler 1975, 1981, Leisler et al. 1989, Schulze-Hagen 1991, AWCT 1999). Nests are built near the ground, typically either on tussocks or suspended in litter (especially in high water conditions), or even directly on the ground if tussocks are not available (Schulze-Hagen 1991, Vergeichik & Kozulin 2006a, Kubacka et al. in prep; see also Chapter 2.5). Because of the uniparental brood care, the species relies on habitats rich in food (Leisler et al. 2002; see also Chapter 2.4).

Hesse (1910) described the peculiarities of Aquatic Warbler habitat selection based on his observations in fen mires northwest of Berlin, Germany: 'I observed the Aquatic Warbler as a characteristic bird for the large fen mires. Among its fellow species of the *Acrocephalus* genus, it is a true 'fen warbler'. Whereas the Great Reed Warbler *Acrocephalus arundinaceus* and the Reed Warbler *A. scirpaceus* are bound to reedbeds, and the Sedge Warbler *A. schoenobaenus* prefers scattered willow shrubs, the Aquatic Warbler invades the vast sedge and rush marshes where no or very few willows persist – the genuine *Caricetum*. Its German name 'Binsen-' or 'Seggenrohrsänger' (Rush or Sedge Warbler) are very much to the point' (translation by F. Tanneberger). In Poland, Taczanowski (1882) compares the Aquatic Warbler with the Sedge Warbler: 'It never inhabits willow shrubs like the other [species], avoids even single, scattered bushes when there are large, rather vast open wild marshlands, either entirely unmown or including vast expanses of such wasteland. Such marshes are covered by thin grass and are locally overgrown by dwarfish reed; they occupy such marshes, both at places entirely without shrubs and those sparsely overgrown with dwarf birches or tiny rosemary-leaved willows. (...) In wet years, it stays in small numbers on meadows during the breeding season, at wet areas with sparse grass' (translation by J. Kloskowski).

Main habitat types

The original natural habitat of the species was probably mesotrophic or slightly eutrophic fen mire, where permanently high water levels and the limited weight carrying capacity of the loose, water-saturated peats prevented tree growth. Since the last glaciation such mires were typical of temperate Europe where they persisted as percolation mires (e.g. in river valleys) or occurred as transient stages in the succession of open water to carrs or bogs (Michaelis 2002).

In recent decades, all such peatlands in Europe have been to some extent degraded (e.g. by drainage, eutrophication, peat compaction, etc.) and continue to be so. Aquatic Warbler breeding has been recorded in five major habitat types with open vegetation, nearly all nowadays depending on human management (such as mowing, grazing, or burning):

- c. 70% of the global population occur in mesotrophic or slightly eutrophic sedge fens with low or medium-sized, partly tuft-forming sedges (mainly *Carex elata*, *C. rostrata*, *C. omskiana*, *C. appropinquata*) and brownmosses (**Fig. 2.3.1** - **Fig. 2.3.5**);
- c. 25% occur in eutrophic floodplain meadows with tussock-forming, medium-sized and large sedges (mainly *Carex acuta*), partly with *Phragmites australis* or scattered bushes (**Fig.2.3.6**);

- <5% occur in calcareous fens with *Cladium mariscus* (**Fig. 2.3.7**);
- <5% occur in wet meadows and pastures with *Phalaris arundinacea* or *Alopecurus pratensis*, partly with sedges (*Carex acuta*, *C. disticha*, and *C. melanostachya*; **Fig. 2.3.8**-**Fig. 2.3.10**);
- <5% occur in brackish meadows and pastures with low *Phragmites australis* (**Fig. 2.3.11** and **Fig. 2.3.12**).

The key characteristics of the breeding habitat – the density of singing males, vegetation structure, and site conditions – are presented in **Table 2.3.1**. Density of singing males (s.m.) ranges from at least 5 s.m./100 ha to more than 100 s.m./100 ha. Kloskowski et al. (2015) reported a maximum of c. 330 s.m./100 ha in the Biebrza National Park. Generally, densities are the highest in mesotrophic sites. Oligotrophic sites with *Sphagnum* mosses are never occupied. Sites with low nutrient availability presumably provide too little food. Sites with increasing nutrient availability are more sensitive to succession by overgrowing bushes and are thus more management-dependent. In strongly eutrophic sites, maintenance of optimal habitat conditions is often only possible by mowing during the breeding season, which may reduce breeding success if nest protection is not secured (see alternating early and late mowing, **Box 4.4.2**).

Vegetation height (0.6-0.8 m in May) and cover of the herb layer (5-30% in May) are similar in all the five breeding habitat types. The thickness of the litter layer and the moss cover differ in relation to the water level, water level fluctuations and nutrient availability (see also Tanneberger et al. 2008). In areas with higher water levels, Aquatic Warblers breed in sites with higher vegetation, a thicker litter layer and/or tussocks and an extensive brown-moss layer (usually oscillating with water level) that enable nest building.

2.3

Area of occupancy

In order to assess how large an area for Aquatic Warbler habitat restoration must be and to provide evidence for the species classification as globally threatened, the area of occupancy (AOO) has been estimated for a large number of breeding sites (**Table 2.3.2**). The AOO is defined as an area actually occupied and calculated using a buffer of 160 m around every singing male recorded during a certain period (which corresponds to the maximum home range of 8 ha as observed by Schaefer et al. 2000). The matrix area between the hypothetical (maxi-mum) home ranges is also included if not obviously unsuitable. In addition, account is taken of any surrounding area that has been assessed as potentially suitable for restoration by habitat management, since the existence of such an area that is sufficiently large seems to be an important prerequisite for habitat selection. The area of the potential habitat (**Table 2.3.2**) consists of the AOO and the potentially suitable area. The key breeding sites in Belarus, Ukraine and eastern Poland (e.g. Zvaniec, Prypiat Valley, Biebrza Valley) have an area of occupancy of at least 1,000 ha, some of more than 2,000 ha (AWCT 1999; **Table 2.3.2**). In contrast, naturally smaller sites and sites that have been affected more severely by habitat loss (often located on the periphery of the current breeding range) have a much smaller area of occupancy of usually 200-1,000 ha (on average c. 400 ha; **Table 2.3.2**). They are typically surrounded by large areas of potentially restorable habitat and may have had an even larger AOO a few decades ago.

Habitat requirements in Belarus

Habitat conditions in all the large Belarusian breeding sites – among them the largest Aquatic Warbler breeding sites in the world – have been extensively studied (Kozulin & Flade 1999, Vergeichik & Kozulin 2006a,b, Vergeichik 2007; see also Chapter 2.5). Population fluctuations in connection with habitat parameters (water level, fires) as well as the density of singing males in favourable years in relation to habitat characteristics were investigated in four large breeding sites in 1999-2005 (**Table 2.3.3**). Zvaniec was studied mainly in 1999, 2001, and 2003-2005, Sporava in 1998, 2000, and 2005, and Dzikoje in 1999 and 2001. In addition to the parameters presented in **Table 2.3.3** (total ion content of soil surface water, plant productivity, and vegetation composition), vegetation height and shrub, reed, and moss cover was also studied in some years with a variety of methods.

In Belarus, the species breeds mainly in mesotrophic peatlands predominated by sedges, with a total ion content in soil surface water of 90-350 mg/l. The total ion content of soil surface water may correlate well with the trophic conditions of a site within a limited range of site types, e.g. fen mires in one biogeographic region. Peatlands with more than 400 mg/l are usually characterised by reed-dominated or meadow vegetation and Aquatic Warblers occur there in small numbers (e.g. Prostyr, Jasieĺda Mouth, Svislač).

◄ **Fig. 2.3.5**
Mesotrophic sedge fen at Supii, Ukraine (photo: M. Flade).

◄ **Fig. 2.3.6**
Eutrophic floodplain meadows at the Upper Prypiat, Ukraine (photo: M. Flade).

◄ **Fig. 2.3.7**
Calcareous fens with *Cladium mariscus* **near Chełm, Poland** (photo: F. Tanneberger).

◄ **Fig. 2.3.8**
Wet meadows and pastures with *Phalaris arundinacea*, *Alopecurus pratensis*, **and sparse sedges (mainly** *Carex acuta*) **in the Lower Oder Valley National Park, Germany** (photo: F. Tanneberger).

► **Fig. 2.3.9**
Wet meadow with low *Carex disticha* **stands in the Nemunas Delta, Lithuania** (photo: Ž. Morkvėnas).

► **Fig. 2.3.10**
Wet meadow in the Hortobágy National Park, Hungary (photo: A. Szilágyi).

► **Fig. 2.3.11**
Brackish meadows with low *Phragmites australis*, **sedges, and abundant** *Thelypteris palustris* **at the Rozwarowo Marshes, Poland** (photo: F. Tanneberger).

► **Fig. 2.3.12**
Brackish meadows at Tyrai, Lithuania, with sand dunes of the Curonian Spit in the background (photo: Ž. Morkvėnas).

Table 2.3.1

Density of singing males, vegetation structure and site conditions in the five main breeding habitat types of the Aquatic Warbler.

Habitat type	Examples	References	Aquatic Warbler density (s.m./100 ha)	Vegetation structure in late May				Site conditions		
				Vegetation height (m)	Herb layer cover (%)	Thickness of litter layer (cm)	Brown-moss cover (%)	Water level in May (cm)	Water level fluctuation April-August (cm)	Nutrient availability[1] (soil C/N ratio)
Mesotrophic and slightly eutrophic fens with medium-sized sedges and brownmosses	Poland/Biebrza Valley	Sellin (1989a), Dyrcz & Zdunek (1993a), P. Marczakiewicz unpubl. data, Wassen & Joosten (1996) J. Kubacka unpubl. data	10-110	0.6-0.8	5-21	high (11-39)	40-100	0-25	low	mesotrophic (21.45±2.2)
	Belarus/Dzikoje, Sporava, and Zvaniec	Kozulin & Flade (1999), Vergeichik & Kozulin (2006a), J. Stepanovich and N. Bambalov pers. comm.	10-135	0.6-0.7	3-20	medium to high (10-35)	60-100	0-10	low (0-20)	mesotrophic (average 19 in Sporava and Zvaniec)
	Ukraine/Udai and Supii	A. Poluda pers. comm., F. Tanneberger unpubl. data	33-115	0.6-0.7	9-11	medium	60-100	0-20	low (<20)	mesotrophic
Eutrophic floodplain meadows with tuft-forming sedges	Poland/Narew Valley, Ukraine/Upper Prypiat, Belarus/Prostyr	Kozulin & Flade (1999), M. Flade unpubl. data	5-23	1.0-1.1	5-20	high	0-5	20-30	high (>50)	eutrophic
Calcareous fens with *Cladium mariscus*	Poland/Chełm	Kloskowski & Krogulec (1999), J. Kloskowski unpubl. data, J. Kubacka unpubl. data	19-36	0.7-1.2	>20	high (27-37)	>20	0-25	low	slightly eutrophic
Wet meadows and pastures with *Phalaris arundinacea* or *Alopecurus pratensis*, partly with sedges	Germany/Lower Oder Valley	Tanneberger et al. (2008), Tanneberger (2008)	7-18	0.4-0.8	5-34	low (0-8)	0	0	high (>50)	eutrophic (10-14)
	Lithuania/Nemunas Delta	Tanneberger et al. (2010a), Knöfler (2012)	7-17	0.4-0.6	0-20	low (0-15)	0	0	high (>50)	eutrophic (10-18)
	Hungary/Hortobágy	Kovacs & Végvári (1999), M. Flade unpubl. data	4-17	0.5-1.0	10-30	medium	0	0-5	low (<20)	slightly eutrophic
Brackish meadows and pastures with *Phragmites australis*	Poland/islands in Świna Delta and Rozwarowo, Lithuania/Curonian Lagoon	Sellin (1989a), Tanneberger (2008), EU-LIFE-project unpubl. data	5-28	0.6-1.0	10-30	low (0-10)	0-20	0-5	low (<20)	slightly eutrophic to mesotrophic (13.4-25.1)

[1]according to mire typology in Succow & Joosten (2001)

Table 2.3.2

Area of occupancy and of potential habitat (see text for definitions) in selected important (past and present) Aquatic Warbler breeding sites.

Breeding site	Period	Number of singing males	Area of occupancy (ha)	Area of potential habitat (ha)	References
BELARUS					
Zvaniec	2010	2,254-4,428	c. 5,700	12,048	Malashevich (2010)
Sporava	2010	501-640	c. 1,019	11,492	Malashevich (2010)
Dzikoje	2008	158-216	c. 904	7,794	Malashevich (2010)
Prostyr	2010	10-50	c. 500	3,079	Malashevich (2010)
Ščara-Dabramysĺ	2010	29-44	c. 123	191	Malashevich (2010)
Servač	2010	31	c. 272	548	Malashevich (2010)
Svislač	2010	37	c. 212	800	Malashevich (2010)
UKRAINE					
Supii Valley between Vilne and M. Berezanka	1995-2010	80-200	220	1,020	Poluda (2009)
Udai Valley between Dorohinka and Monastyryshche	1997-2010	140-360	420	1,420	Poluda (2009)
Halka Valley (basin of Udai)	2005-2009	20-35	80	210	Poluda (2009)
Prypiat Valley south of Nevir	2008-2010	300-350	600	2,100	Poluda (2009)
Valley of rivers Prypiat and Tsyr near Birki	2009-2010	1,400-1,600	1,900	2,700	Poluda (2009)
Prypiat Valley (left bank) between Vetly and Lubotin	2006-2010	400-500	500	1,300	Poluda (2009)
POLAND					
Biebrza Valley	2003-2009	2,061-2,577	9,367	no data	LIFE-Projekt GIS[1]
Chełm Marshes	2003-2009	208-303	810	4,300	LIFE-Projekt GIS[1]
Rozwarowo	2003-2009	20-37	322	1,300	LIFE-Projekt GIS[1]
Islands in Świna Delta	2003-2009	11-39	900	1,200	LIFE-Projekt GIS[1]
Miedwie	1990-2004	4-14	200	1,200	LIFE-Projekt GIS[1]
Krajnik/Gryfino	2003-2009	3-6	52	c. 10,000[2]	LIFE-Projekt GIS[1]
Warta Mouth National Park	1969-1972	up to 50	c. 650	c. 15,000	Nowysz & Wesołowski (1972)
Warta Mouth National Park	2003-2009	3-11	162	c. 15,000	LIFE-Projekt GIS[1]
Łąki Husynne (Bug)	2009	54	c. 200	no data	M. Maniakowski pers. comm.
Bagno Kramskie	1971-1979	50-300	400	no data	Nawrocki et al. (1982)
Łąki Żelizna	2012-2013	At least 8-9	c. 100	no data	J. Kloskowski unpubl. data
GERMANY					
Lower Oder Valley National Park	1986-2004	8-34	c. 3,600	c. 10,000[2]	LIFE-Projekt GIS[1]
Lower Oder Valley National Park	2005-2009	0-10	c. 2,000	c. 10,000[2]	LIFE-Projekt GIS[1]
Freesendorfer Wiesen/Struck	1988-1995	8-32	c. 120	470	Sellin (1989a)
Rietzer See	1967-1970	15-25	c. 180	no data	Wawrzyniak & Sohns (1977);
Schadefähre	1972-1975	20	⩾100	ca. 3,000	LIFE-Projekt GIS[1]
LITHUANIA					
Sausgalviai	2004-2006	14	c. 800	c. 15,000	F. Tanneberger unpubl. data
Šysa	2004-2006	50-60	c. 1,000	c. 15,000	F. Tanneberger unpubl. data
HUNGARY					
Hortobágy National Park	1971-2010	9-706	6,020	16,602	Z. Végvári unpubl. data

[1] Monitoring database of the LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (OTOP/F. Tanneberger)
[2] Areas share a common area of potential habitat

2.3

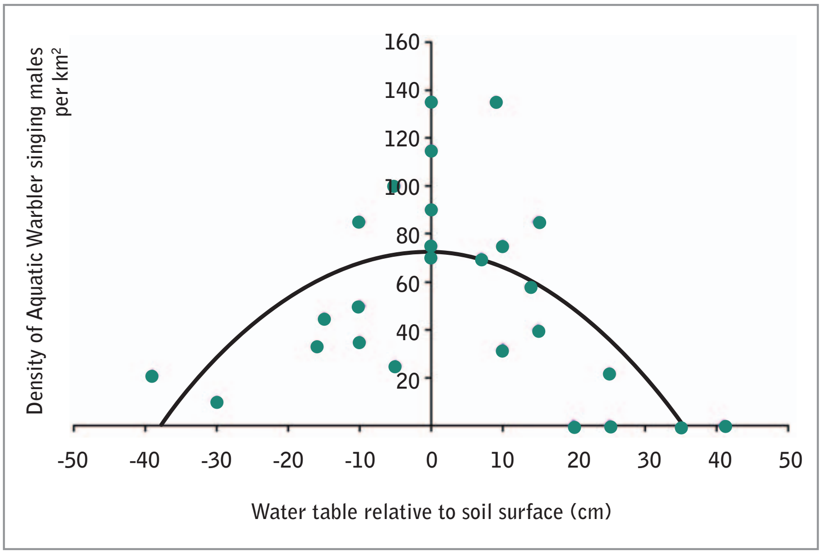
In transitional peatlands with less than 80 mg/l (e.g. Dzikoje), Aquatic Warblers also occur only in small numbers. Here, the occurrence of *Sphagnum* mosses indicates that the habitat is unsuitable for the species.

The density of singing males varied with nutrient availability and associated plant biomass productivity. In each of the four study sites, which are all mesotrophic, Aquatic Warbler density seemed to be associated with the total ion content of the surface water (**Table 2.3.3**). However, eutrophic sites, such as Prostyr, showed a lower density of singing males (**Table 2.3.1**). In the more nutrient-rich study sites there was a higher proportion of Caricetum elatae, whereas the less nutrient-rich sites exhibited a higher proportion of Caricetum lasiocarpae and Caricetum limosae. At the same time, densities and numbers of birds were affected strongly by changes in the groundwater table caused e.g. by floods, as well as by the occurrence of droughts or fires (see also Chapter 2.5). Aquatic Warblers bred successfully when the groundwater table coincided with the topsoil level; the optimal water table lay in the range from 12 cm above to 5 cm below the soil surface (**Fig. 2.3.13**).

Habitat requirements in Eastern Poland

The East-Polish Aquatic Warbler breeding sites are mostly mesotrophic. The main site is placed in the Lower Biebrza Basin. These habitats are not subject to river floods, but are very wet thanks to permanent groundwater seepage and very slow rainwater run-off. The groundwater originates from the moraine and is relatively base-rich, with a high calcium and low phosphorus content (Wassen 1990). The site is occupied by species-rich plant communities with medium size and low species such as *Carex appropinquata*, *C. elata*, and *C. lasiocarpa*. The very well-developed moss layer is composed mostly of brownmosses. Common vascular plants are Bogbean (*Menyanthes trifoliata*), Marsh Cinquefoil (*Potentilla palustris*), and Marsh Fern (*Thelypteris palustris*).

In order to identify key parameters of Aquatic Warbler habitat selection in eastern Poland, a 'best habitat' study (Kloskowski et al. 2015) was conducted from late May to late June in 2007-2010. Surveys of singing males were conducted on 60 transects of 100 x 1,000 m, randomly chosen with regard to the presence of Aquatic Warblers in the study area. The transects were located in current breeding sites (51 transects in the Biebrza Valley, four in the



▼ Fig. 2.3.13
Relationship between Aquatic Warbler density (males/km²) and water table (cm below or above soil surface) at Sporava (study plots Piasčanka and Kasciuki), Belarus. R^2=0.42, p<0.01.

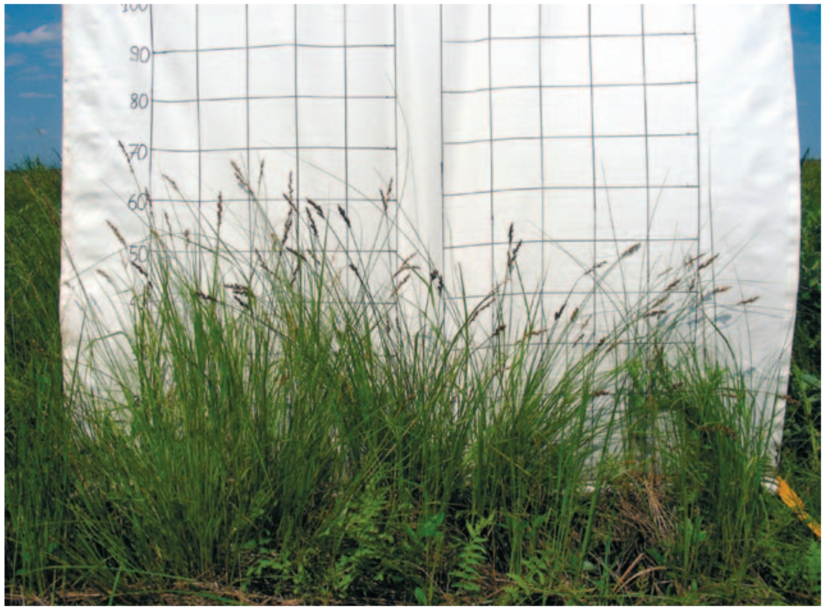
▼ Table 2.3.3
Aquatic Warbler density and habitat characteristics of main monitoring plots in Belarus in the period 1996-2005 (Vergeichik 2007 and A. Kozulin unpubl. data). Total ion content of soil surface water and plant productivity are maximum values recorded in years with highest Aquatic Warbler density with 3 replicates. Between-year differences were low (A. Kozulin pers. comm.). The proportion of main vegetation types is given for transects studied by Stepanovich (2006).

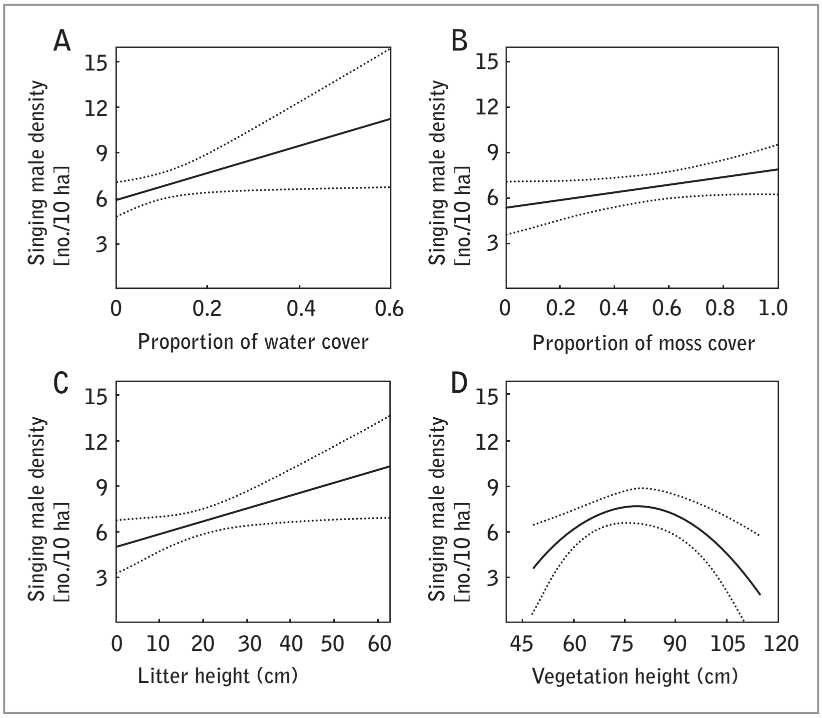
Habitat parameter	Peatland and monitoring plots							
	Sporava			Zvaniec		Dzikoje		Servač
	Piasčanka	Kasciuki	Kakoryca	Navasiolki	Pavicce	Vybrady	Juzefin	
Density (s.m./100 ha)	135	90	100	90	103	63	9	12
Total ion content of soil surface water (mg/l)	322	145	163	150	280	107	85	90
Plant productivity (g/m²)	272	157	189	213	245	125	100	110
Caricetum elatae (%)	89	81	38	13	58	10	0	0
Caricetum appropinquatae (%)	0	0	13	4	37	5	0	0
Caricetum lasiocarpae (%)	0	5	39	50	0	45	55	65
Caricetum limosae (%)	0	0	0	0	0	16	30	20

Poleski National Park, three in the Narew Valley, and two in the Chełm Marshes). The fieldwork was carried out mainly by volunteers (S. Bärisch, F. Griffault, A. Wiśniewska, J. Daebeler, A. Nowogrodzka, M. Miklos, M. Trubridge) with support from the LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany'. To facilitate comparability, both vegetation and invertebrate sampling was done based on the LIFE project's monitoring guidelines. Variables expected to be important to the Aquatic Warbler were measured: herbaceous vegetation height and cover, water depth and cover, moss cover, litter thickness and cover, number and height of bushes along a transect, as well as abundance of arthropod prey, evaluated with sweep-netting and yellow pan traps.

The results indicated that the density of Aquatic Warbler singing males increased with water cover, moss cover and litter height, and was the highest at intermediate vegetation heights (c. 60-90 cm; **Fig. 2.3.14** and **Fig. 2.3.15**). Water cover also interacted with litter height, such that in areas with higher water cover (and presumably water depth) litter thickness negatively affected male numbers, most likely through limited foraging opportunities. In addition, male densities positively correlated with the biomass of large arthropod prey (>10 mm) and of spiders. The remaining variables were of little importance to the density of singing males (Kloskowski et al. 2015).

Presence of surface water likely provides sufficient arthropod abundance and safeguards the birds against mammalian predators. Litter offers cover for a nest, protecting it from wind or rain, and hiding it from predators such as shrews or snakes; it can also be related to arthropod abundance. A thick moss cover likely indicates the capability of the mire to buffer sudden changes in the water table. The optimal vegetation height of 60-90 cm could reflect the adaptation of the Aquatic Warbler to climbing on plants of intermediate height and a trade-off between higher predation risk in low vegetation and the difficulty to forage in tall (and likely also dense) vegetation. The positive relation between singing male density and the biomass of large prey and spiders are in line with the earlier findings that Aquatic Warblers feed on relatively large arthropod classes and that spiders may be an important nestling food source (Schulze-Hagen et al. 1989).





▲ **Fig. 2.3.14**
Optimal vegetation structure in the Ławki Mire, Biebrza Valley, Poland (photo: S. Bärisch).

▲ **Fig. 2.3.15**
Optimal habitat conditions for the Aquatic Warbler in Eastern Poland (from Kloskowski et al. 2015).

Habitat requirements in Ukraine

Also the main Ukrainian breeding sites are mesotrophic (**Table 2.3.1**, Poluda et al. 2007, Poluda 2009). At Supii (**Fig. 2.3.5**), the diverse fen vegetation is dominated by *Carex appropinquata*, with scattered *Typha latifolia* and bushes of *Salix cinerea*. Substantial areas are also occupied by *C. rostrata*, *C. lasiocaropa*, and *Menyanthes trifoliata*. Brownmosses are widespread, and *Drepanocladus aduncus* prevails together with *Bryum pseudotriquetrum* and *Amblystegium serpens*.

At Udai, typical plant species of mesotrophic fen mires prevail: *Carex appropinquata*, *C. omskiana*, *C. lasiocarpa*, *C. rostrata*, *Menyanthes trifoliata*, *Potentilla palustris*, *Lysimachia thyrsiflora*. Less common are *Typha latifolia* and *Phragmites australis*. *Salix cinerea* is typical, and on dry areas, it is *S. rosmarinifolia*. Closer to the periphery of the mire, *Carex acuta* occurs. Very typical is the presence of brownmosses.

All over central Ukraine, the Aquatic Warbler mainly lives in mesotrophic mires or in eutrophic mires with mesotrophic elements. In contrast, in Volyn Aquatic Warblers inhabit largely eutrophic sites (**Table 2.3.2**). These are mainly the floodplains of Prypiat, Stokhid, Styr, and Chornohuzka.

Habitat requirements in Pomerania

In Pomerania, all the current and a large number of recently abandoned Aquatic Warbler breeding sites were studied during 2004-2006 (Tanneberger 2008) to identify key parameters in habitat selection. The Pomeranian Aquatic Warbler breeding sites are mostly eutrophic (**Table 2.3.4**; Tanneberger et al. 2010, 2011). The habitats in the coastal and small river valley sites (Rozwarowo, Wolin National Park, Karsiborska Kępa, Zajęcze Łęgi, Miedwie) are slightly eutrophic, whereas the Lower Oder/Odra Valley habitats (Krajnik, Lower Oder Valley National Park, Warta Mouth National Park) are strongly eutrophic.

The vegetation belongs to five vegetation forms (after Koska et al. 2001; **Table 2.3.4**) and five associations from three alliances (Caricion lasiocarpae, Magnocaricion elatae, and Scirpetum maritimi, after Rennwald 2000). Although they have a common vegetation structure making them suitable for the Aquatic Warbler, the Pomeranian habitats vary considerably in respect of plant composition, which is related to differences in water regime (dikes/no dikes) and land use (**Table 2.3.4**).

In a very small area, the Pomeranian habitats reflect the overall variety of Aquatic Warbler breeding habitats: Rozwarowo and Miedwie are rather similar to eastern Polish and Belarusian mesotrophic percolation fen habitats. The coastal habitats on Karsiborska Kępa and in the Wolin National Park are the most similar to the Lithuanian coastal habitats at the Curonian Lagoon. The Lower Oder Valley sites have key features in common with the Lithuanian Nemunas Delta habitats and some floodplain habitats in Belarus, Ukraine and eastern Poland (Narew).

To characterise the optimal habitat in Pomerania and to derive management recommendations, the soil C/N ratio is of great importance (Tanneberger et al. 2010a). The probability of occurrence of Aquatic Warblers is higher on less eutrophic sites (i.e. on sites with higher C/N ratios), as is the density of males. With mean values in late May/early June of c. 0.5 cm above the ground, the water level is much lower than in the core population habitats (5-10 cm; Kozulin & Flade 1999, Dyrcz & Zdunek 1993a). For a high probability of Aquatic Warbler occurrence in more eutrophic sites, at least a part of the site needs to be mown early (before the end of July) in the preceding year, and the thickness of the litter layer should not exceed 10 cm (Tanneberger et al. 2008, 2010a; **Fig. 2.3.16**). This is in complete contrast to the waterlogged or water-saturated sites, where mowing is not so necessary and can even be detrimental because the litter layer has to be thick to allow for nest-building above the water surface (c. 20 cm; Dyrcz & Zdunek 1993a, Vergeichik & Kozulin 2006a). This was also true in breeding areas in Germany before the land use and drainage increased to a detrimental level (Heise 1970a). With regard to vegetation structure, optimal conditions during late May/early June include a vegetation height of less than 70 cm, a cover of the lower herb layer of c. 20% and of the upper herb layer of less than 60%, i.e. rather sparse vegetation. Such vegetation can probably be more easily used for climbing and foraging (Leisler 1981, Leisler et al. 1989) and provides abundant food (Tanneberger et al. 2013). In contrast, dense vegetation and a thick litter layer probably have an adverse effect on larval development of arthropods and especially on the abundance of nectar-collecting insects, which constitute an important part of the diet. In contrast to the habitats in eastern Poland and Belarus that are described as homogeneous (Dyrcz & Zdunek 1993a, Kozulin & Flade 1999, Leisler 1981), Pomeranian habitats are more heterogeneous (Tanneberger 2008), i.e. they comprise a mosaic of patches with lower and higher vegetation. This may be related to better food supply along the edges and between such patches.

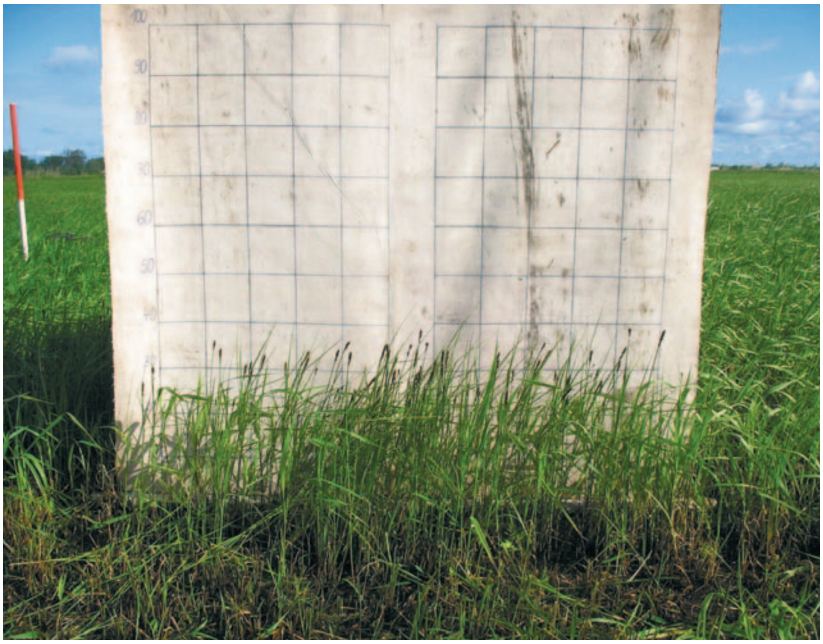
▲ **Fig. 2.3.16**

Former Aquatic Warbler breeding site with unsuitable dense and high vegetation and a thick litter layer in the Warta Mouth National Park, Poland (photo: F. Tanneberger).

▼ **Table 2.3.4**

Vegetation and site characteristics of Pomeranian Aquatic Warbler breeding sites (from Tanneberger et al. 2010a, slightly modified). Land use types: WM = winter mowing; SM = summer mowing; GR = grazing.

Name	Location	Main soil type	Nutrient availability	Vegetation form (after Koska et al. 2001)	Dominant plant species	Indicated moisture class	Main land use type	Number of singing males 2007-2016
Rozwarowo	small river valley (partly with dikes)	peat	eutrophic – mod. rich	mainly *Calliergonella cuspidata-Carex elata* reed	reed	wet	WM	8-36
Wolin National Park	islands in Świna Delta (no dikes)	peat	eutrophic – mod. rich	*Aster tripolium-Phragmites australis* reed	reed	very moist to wet	WM, SM, GR	2-10
Karsiborska Kępa	island in Świna Delta (with dikes)	peat	eutrophic – mod. rich	*Aster tripolium-Phragmites australis* reed	reed	very moist to wet	WM, SM, GR	0-15
Zajęcze Łęgi	peninsula in Świna Delta (with dikes)	peat	eutrophic – mod. rich	*Aster tripolium-Phragmites australis* reed	reed	very moist to wet	WM, SM, GR	0-2
Miedwie	adjacent to lake (no dike)	peat	eutrophic – mod. rich	*Ranunculus lingua-Carex elata* reed	sedge	wet	SM, GR	0
Krajnik	Oder polder area (with dikes)	peat	eutrophic – rich	*Caltha palustris-Filipendula ulmaria* tall herb vegetation	sedge	very moist	SM	0-5
Lower Oder Valley National Park	Oder polder area (with dikes)	mineral soil	eutrophic – rich	*Poa palustris-Phalaris arundinacea* reed	sedge	wet	SM, GR	0-10
Warta Mouth National Park	Warta floodplain (no dike)	peat	eutrophic – rich	*Poa palustris-Phalaris arundinacea* reed	sedge	wet	SM, GR	0-11



▲ **Fig. 2.3.17**
Aquatic Warbler habitat in the Sausgalviai polder in the Nemunas Delta, Lithuania (photo: F. Tanneberger).

Habitat requirements in Lithuania

Habitat conditions in Lithuanian Aquatic Warbler breeding sites were first comprehensively studied in 2006 (Tanneberger 2008, Tanneberger et al. 2010a), with similar methods again in 2011 (Knöfler 2012), and from 2011 onwards monitoring of vegetation communities was implemented as part of the LIFE projects (Baltic Aquatic Warbler 2010-2015, LIFE09 NAT/LT/000233; MagniDucatusAcrola 2016-2023, LIFE15 NAT/LT/001024).

The floodplain polders of Šyša and Sausgalviai in the Nemunas Delta are characterised by regularly mown Reed Canary Grass (*Phalaris arundinacea*) meadows with patches of sedges (mainly *Carex disticha*, partly *C. acuta* and *C. vulpina*), a rich layer of herbs (e.g. *Lysimachia nummularia*, *L. vulgaris*, *Galium palustre*, *Ranunculus repens*, and *Cardamine pratensis*), a vegetation height in May of 0.4-0.6 m, and a litter layer of 0-15 cm (Tanneberger et al. 2010a; **Fig. 2.3.17**). Site conditions are eutrophic: the soil C/N in Šyša (N=27) is 13.8 ±1.6, that in Sausgalviai (N=22) is 13.3 ±1.8. A peat layer is present in all sites, with an organic matter content of 52.2% ±15.9% (Šyša) and 73.1% ±4.4% (Sausgalviai), respectively (Knöfler 2012). In the Šyša polder, in the period 2011-2015 areas with Phalaridetum arundinaceae progressively increased: from 37.6% (2011) up to 46.6% (2015). In 2013, due to prolonged floods in the polder, Caricetum distichae communities almost vanished and they were replaced by Phalaridetum arundinaceae and Caricetum gracilis (some plots by Lysimachio-Filipenduletum; Balsevičius & Narijauskas 2015).

Tyrai is a coastal flood mire at the shore of the Curonian Lagoon. Recently, Aquatic Warblers have concentrated in the southern part of the mire, dominated by sedges (mainly *C. disticha*). The large northern part of the mire currently is dominated by Reed (*Phragmites australis*). The site is eutrophic (soil C/N ratio 16.5 ±2.5). The peat soil has an organic matter content of 74.6 ±11.2% (Knöfler 2012). In the period 2011-2015, a substantial decrease of the cover of Phragmitetum australis plant community was recorded due to intensive mowing (1-3 times/year). Along with reed growth suppression, Aquatic Warblers spread across the entire peatland. It is likely that in wetter habitats Caricetum elatae will develop and in drier ones Caricetum distichae will expand (Balsevičius et al. 2015a).

The Aquatic Warbler habitats at the Žuvintas Biosphere Reserve are fen peat soils covered mainly by Thelypteridi-Phragmitetum (155.9 ha), with smaller patches of Caricetum distichae (14.8 ha), Caricetum appropinquatae (6.7 ha), and Caricetum elatae (4.6 ha). During the last 15 years, a decline in the extent of these communities has been observed and due to expansion of reeds, they are being replaced by Thelypterido-Phragmitetum (Balsevičius et al. 2015b). The reintroduction of mowing by the EU LIFE project starting in 2010 initiated a reverse development: reedbeds (Thelypterido-Phragmitetum) started to transform into Caricetum elatae. In mown reedbeds *Carex elata* started to flourish and new juvenile individuals of this sedge appeared. Plant communities of *Carex elata* had covered this area before it was abandoned by Aquatic Warblers (Balsevičius et al. 2015b).

Habitat requirements in Hungary

In modern times, the entire Hungarian population bred in a single site, the Hortobágy National Park. Breeding habitats are classified into the Natura 2000 habitat type referred to as 'Pannonic salt steppes and marshes'. Within this habitat class, Aquatic Warblers occupied primarily alkali wet grasslands dominated by *Alopecurus pratensis* with other main species being *Beckmannia eruciformis* and *Glyceria fluitans*, with varying cover depending on salinity (**Table 2.3.1**, **Fig. 2.3.10**, Kovács & Végvári 1999). Importantly, the majority of Aquatic Warbler breeding habitats included sedges with a highly variable cover, mainly *Carex melanostachya*. In exceptionally dry years, the species bred in moist grasslands dominated by *Agropyron repens*.

2.4 Food and foraging

FRANZISKA TANNEBERGER, MARGARITA MINETS & ALEXANDER KOZULIN

Aquatic Warbler diet, food resources, and foraging behaviour during the breeding season have been studied mainly in Belarus and eastern Poland (Schulze-Hagen et al. 1989, Dyrcz & Zdunek 1993a, A. Kozulin unpubl. data). From other breeding areas, there are qualitative descriptions of the diet, for example at the Rietzer See, now abandoned by the species (Heise 1970b), and reports on foraging characteristics (Wawrzyniak & Sohns 1977, Tanneberger et al. 2013). There are also a number of studies documenting the diet and foraging behaviour of Aquatic Warblers at stop-over sites during post-nuptial migration (e.g. Provost et al. 2010, Kerbiriou et al. 2011, Musseau et al. 2014, Miguelez et al. 2016).

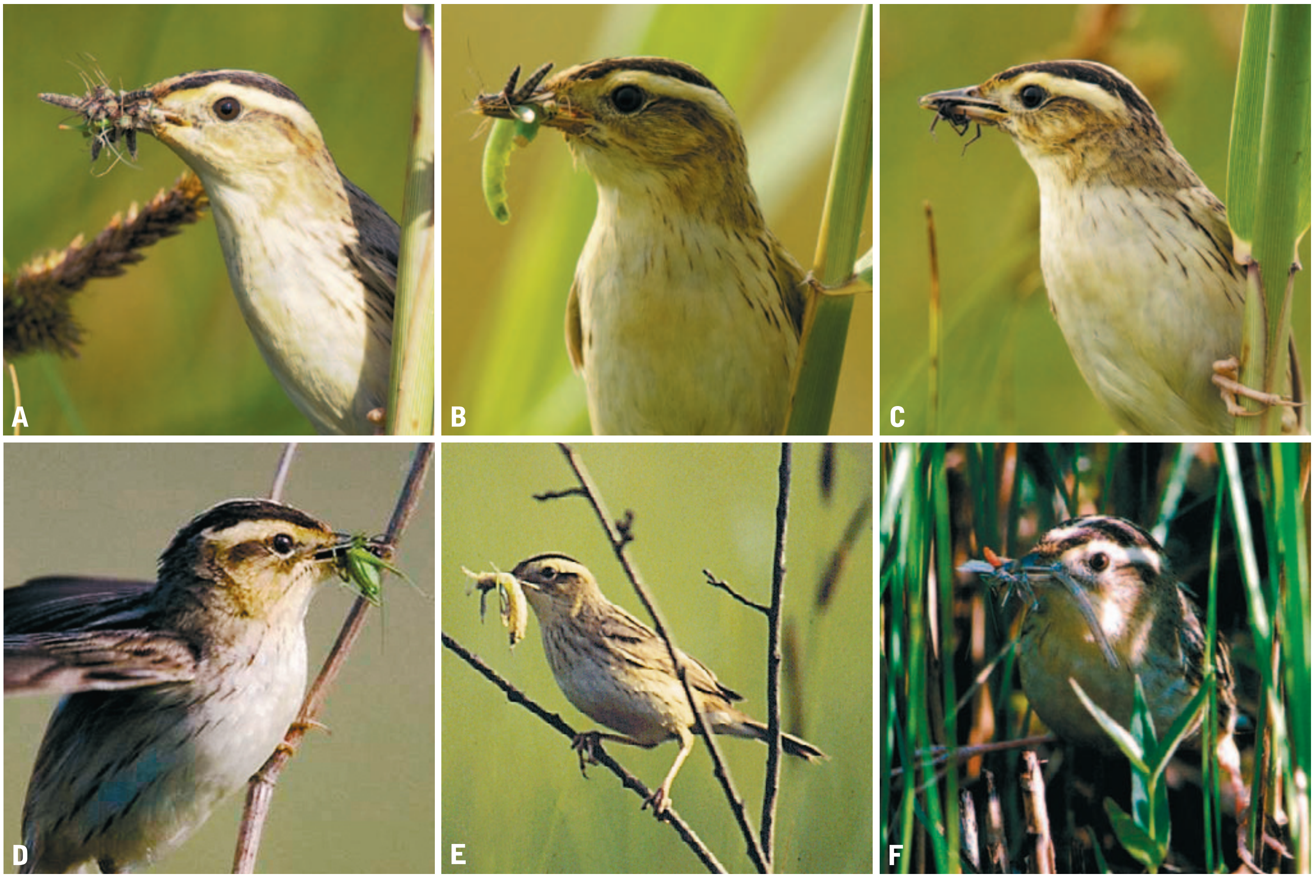
Diet and foraging in the breeding season

Aquatic Warblers prefer to forage by climbing within the upper vegetation layer (Leisler 1975, Leisler et al. 1989, Schulze-Hagen et al. 1989). They feed on all the main invertebrate taxonomic groups available in their habitats, which can also be found in sweep net samples (Schulze-Hagen et al. 1989, A. Kozulin unpubl. data). Prey (**Fig. 2.4.1**) consists mainly of insects, predominantly flies (Diptera), ants and bees (Hymenoptera), butterflies (Lepidoptera), grasshoppers (Orthoptera), dragonflies (Odonata), and of spiders (Araneae). Their proportion in food differs substantially between the first and second clutch, and prey composition generally shows large temporal and site-specific differences (**Table 2.4.1**, A. Kozulin unpubl. data).

The mean length of prey items is c. 7-9 mm, with a mean dry weight of c. 4-7 mg (Schulze-Hagen et al. 1989; A. Kozulin unpubl. data). In contrast to the Sedge Warbler *Acrocephalus schoenobaenus*, in two breeding sites Aquatic Warblers fed also on heavy prey items of >75 mg dry weight (**Fig. 2.4.2**; Tanneberger et al. 2013). The prey load contains on average 1-4 prey items (Dyrcz & Zdunek 1993a; A. Kozulin unpubl. data) and has a dry weight of c. 20-30 mg (A. Kozulin unpubl. data). The prey-delivery rate under research conditions is 0.7 mg per minute per nestling (Tanneberger at al. unpubl. data). The feeding frequency is generally high; Schulze-Hagen et al. 1989 observed intervals of c. 2 min over

Table 2.4.1
Composition of the diet of Aquatic Warbler nestlings as a percentage of the total number (N) or the total dry biomass (M) of prey in the largest Polish and Belarusian breeding sites.

	Poland, Biebrza Valley	Poland, Chełm Marshes	Belarus, Zvaniec	Belarus, Zvaniec
Reference	Schulze-Hagen et al. (1989)	Wołoszkiewicz et al. in prep.	A. Kozulin unpubl. data	A. Kozulin unpubl. data
Study period	first clutch (early June)	first and second clutch (May-July)	first clutch (June)	second clutch (July)
Study years	1983-1987	2014	2001-2005	2001-2005
Nests	17	18	21	11
Prey items	2,956	244	841	538
Prey composition	N	N	M	M
Spiders (*Aranea*)	30.5	18.4	14.1	12.9
Beetles (*Coleoptera*)	15.0	<1%	9.1	0
Flies (*Diptera*)	15.6	<1%	26.1	5.5
True bugs (*Hemiptera*)	-	<1%	1.0	2.8
Ants and Bees (*Hymenoptera*)	1.0	<1%	9.2	1.9
Butterflies (*Lepidoptera*)	20.5	14.3	15.3	15.7
Dragonflies (*Odonata*)	0.8	2.9	1.7	29.6
Grasshoppers (*Orthoptera*)	0.8	60.2	3.0	30.1
Caddisflies (*Trichoptera*)	7.8	<1%	5.8	0



▲ **Fig. 2.4.1**
Aquatic Warbler with prey (photos: **A-C** Ž. Morkvėnas, **D** RSPB, and **E-F** A. Kozulin).

longer periods of feeding. The number of feeding visits per hour and nestling in broods with four nestlings was 1.4 in the second day of their life and 7.9 in their 15th day of life (N=9, Dyrcz 1993). Wołoszkiewicz et al. (in prep.) observed an average frequency of brood feeding of every 5.2 min, which is very high relative to provisioning frequencies observed in earlier studies (Schulze-Hagen et al. 1989, Dyrcz 1993). Most of the video-taped nests were located at a wet calcareous meadow that is mown every two years, which likely creates favourable conditions for arthropods, providing a relatively high amount of green vegetation, and could partly explain the high feeding frequency. Heise (1963) describes an average duration of feeding of 17 hours per day, which is exceptionally long for small passerines.

Average flight distances of females collecting food for nestlings are similar in Belarus (A. Kozulin unpubl. data: 25 m; **Fig. 2.4.3**) and eastern Poland (Schulze-Hagen et al. 1989: 18 m; Dyrcz & Zdunek 1993a: 32 m), but significantly higher in Pomerania (Tanneberger et al. 2013: 60 m; see **Box 2.4.1**). In contrast, the Sedge Warbler has similar foraging flight distances of 20-40 m in Pomerania (F. Tanneberger unpubl. data) and Belarus (A. Kozulin unpubl. data). Many other passerine species show much longer foraging flights, e.g. an average of 60-100 m in the Reed Bunting (F. Tanneberger unpubl. data from Pomerania).

A high abundance of potential prey is likely to be an essential prerequisite for successful breeding in the Aquatic Warbler because females feed the four to five nestlings alone (Leisler & Catchpole 1992). In Pomerania, the total invertebrate biomass was found to be significantly larger in sites where Aquatic Warblers occurred (compared to recently abandoned sites) and with low and less dense vegetation, either thanks

2.4

Box 2.4.1
Foraging characteristics of brood-provisioning females in Pomerania

FRANZISKA TANNEBERGER

As part of a larger study on the habitat requirements of Aquatic Warblers in Pomerania (Tanneberger 2008), food and foraging were studied on nine nests at five sites in 2006. Aquatic Warblers feeding their nestlings in Pomerania flew more than twice as far as reported from breeding sites in eastern Poland and Belarus (**Fig. 2.4.3**). Moreover, in seven out of nine nests they preferred to forage in vegetation of diverse height and species composition, as is caused by differences in relief (slopes, depressions, ditches) or fine-scale land use (Tanneberger et al. 2013). Such selective foraging flights have not been observed in other breeding populations.

In Pomerania, the selection of mown areas for foraging can be explained by the availability of invertebrates. Such sites have low and sparse vegetation and lack a thick litter layer (Tanneberger et al. 2008, 2010a), resulting in favourable microclimatic conditions for the larval development of e.g. grasshoppers (Orthoptera) and several spiders (Araneae), beetles (Coleoptera), and flies (Diptera). The rich herb layer favours larvae developing on herbs as well as pollen- and nectar-collecting insects, e.g. caddisflies (Trichoptera), butterflies (Lepidoptera), ants and bees (Hymenoptera). The highly nutritious fresh plant material is preferred by some true bugs (Hemiptera), Araneae, and some Hymenoptera larvae. The sparsity of vegetation also favours Araneae and beetles (Coleoptera). In addition, the birds can more easily detect food and climb in such more open sites (Wilson et al. 2005). These effects are less pronounced during the second brood when the herb layers in mown and unmown sites have similar cover and density, and the above ground microclimatic differences are smaller (Tanneberger et al. 2013).

A particular vegetation structure and microclimate probably supports invertebrate biomass at edges, ditches and depressions (Tanneberger at al. 2013). In lower vegetation, especially when shaded by higher vegetation, the warmer, sunnier and wind-protected conditions are more favourable for many invertebrates (Báldi & Kisbenedek 1999). A preference for foraging along edges was also described for the Moustached Warbler *Acrocephalus melanopogon* (Leisler 1991, Taylor 1993), and for the Reed Warbler *A. scirpaceus*, Marsh Warbler *A. palustris*, and Sedge Warbler (Surmacki 2005). In addition, the moister conditions in ditches and depressions make these favourable for many arthropods (Brunel et al. 1998, Schaefer 2006).

Long foraging flight distances are likely to incur greater costs in terms of energy expenditure and predation risk. Particularly for a species with uniparental care, this may reduce breeding success (Leisler & Catchpole 1992, Dyrcz 1993, Schulze-Hagen et al. 1999). The presence of fledged young at seven of the nine nests studied in 2006 and thus in most Pomeranian breeding sites suggests that Aquatic Warblers can still breed successfully, although this should be interpreted with caution for the small sample size. The similar delivery rates of Sedge Warblers observed on Aquatic Warbler breeding sites in Pomerania and Belarus support the conclusion that in current nesting sites Aquatic Warbler ►

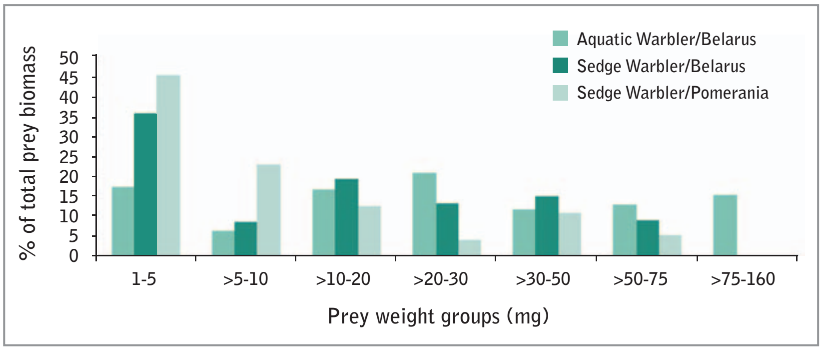
to mowing or to a naturally low trophic level. Of all Pomeranian sites studied in 2006, the total invertebrate biomass was the highest on sites with mown sedge vegetation (median per sweep netting transect: 475 mg dry weight) and the lowest on sites with unmown reed vegetation (55 mg). Unmown sedge vegetation had a slightly lower biomass (299 mg) than mown reed vegetation (346 mg; Tanneberger et al. 2013). In Rozwarowo (Pomerania), slightly eutrophic mown reed and sedge vegetation provided much more potential Aquatic Warbler food (median per sweep netting transect: 684 mg) than strongly eutrophic mown reed vegetation (147 mg; Tanneberger et al. 2009). These results may be biased by the larger resistance of unmown, i.e. high and dense, vegetation to sweep netting but nonetheless would also reflect lower availability ('catchability') of prey for Aquatic Warblers. The general pattern may also be true in other breeding sites.

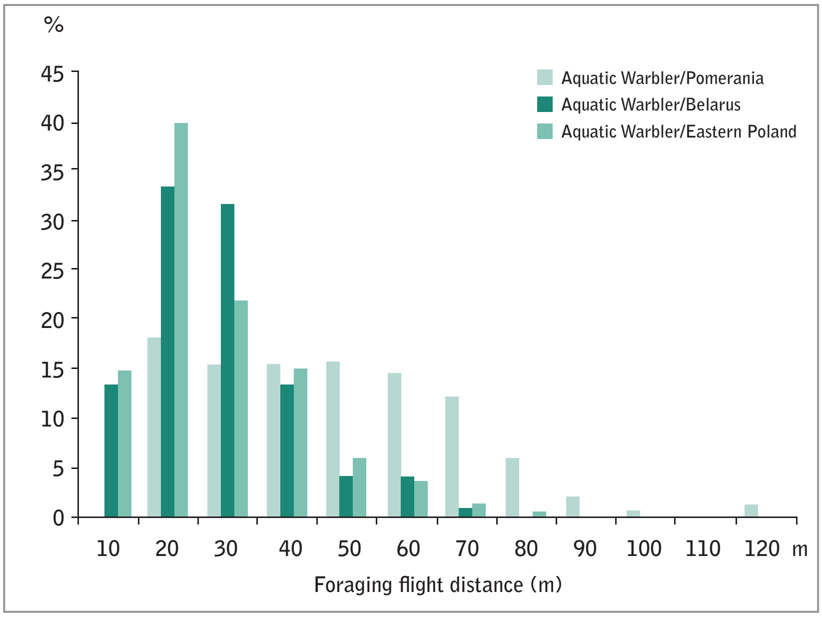
Food and foraging during migration

Aquatic Warbler diet during autumn migration was studied at stopover sites in France and Spain by identification of invertebrate taxa in faeces. In a comprehensive analysis based on 128 individuals captured over four years at the Audierne Marsh in western France, Kerbiriou et al. (2011) found that the largest fraction of consumed biomass was made by Odonata, Araneida, Orthoptera, Diptera, and Lepidoptera (43, 13, 12, 9, and 8%, respectively). The groups contributing most by biomass in the Seine Estuary in northern France, as observed in 15 individuals, were Odonata, Lepidoptera, Coleoptera, Araneida, and Heteroptera (39, 21, 11, 9, and 9%, respectively; Provost et al. 2010). Musseau et al. (2014) studied Aquatic Warblers stationing at a stopover site in France over three years. They found that Orthoptera, Araneae, and Hymenoptera formed the highest contribution to the consumed biomass of arthropods (64.7, 13.4, and 8.9%, respectively). As shown by radio-tracking, the Aquatic Warblers had relatively small foraging ranges (6.6±2.6 ha) and preferred partially-flooded or flooded habitats with heterogeneous and rather low vegetation, such as bulrush beds or bulrush beds mixed with reed beds. Prey remnants in faeces sampled from 29 Aquatic Warblers in Baie de l'Aiguillon (western France) in 2014 were largely from Hemiptera (34%) and Araneida (29%), but also from Diptera (11%), Hymenoptera (10%), and Lepidoptera (10%; Gonin & Mercier 2016).

Data from 12 Aquatic Warblers caught at the El Villar Lagoon in Spain (Miguelez et al. 2016), showed that 86% of the consumed biomass consisted of Diptera, Odonata, Orthoptera, and Araneae. Taking into account availability of different prey groups in the habitat, high preference was found for Odonata, Orthoptera, Araneae, and Lepidoptera. Foraging range size was on average 9 ha and daily core ranges were just above 1 ha; wet grassland was preferred to reedbeds. Overall, these findings indicate that selection of food and foraging habitat during migration is similar to that on breeding grounds.

Box 2.4.1 contd food is not in short supply. Foraging and nesting places seem to be more separated than in other breeding sites. Since neither delivery rates nor the breeding productivity of Pomeranian Aquatic Warblers have been measured, a negative effect of increased foraging distances on breeding success cannot be completely discounted.





▲ **Fig. 2.4.2**

(top) Contribution (%) of prey weight groups (mg) to the total prey biomass fed by Aquatic Warblers to nestlings in Belarus (18 nests, N=849 prey items) and Sedge Warblers in Belarus (13 nests, N=908) and Pomerania (4 nests, N=622; A. Kozulin & F. Tanneberger unpubl. data**).**

▲ **Fig. 2.4.3**

(bottom) Frequency distribution of foraging flight distances (m) of Aquatic Warbler females in Pomerania (9 nests, N=246 foraging flights; Tanneberger et al. 2013**), Belarus (12 nests, N=121 ;** A. Kozulin unpubl. data**), and eastern Poland (8 nests, N=350;** Schulze-Hagen et al. 1989**).**

2.5 Breeding biology and ecology

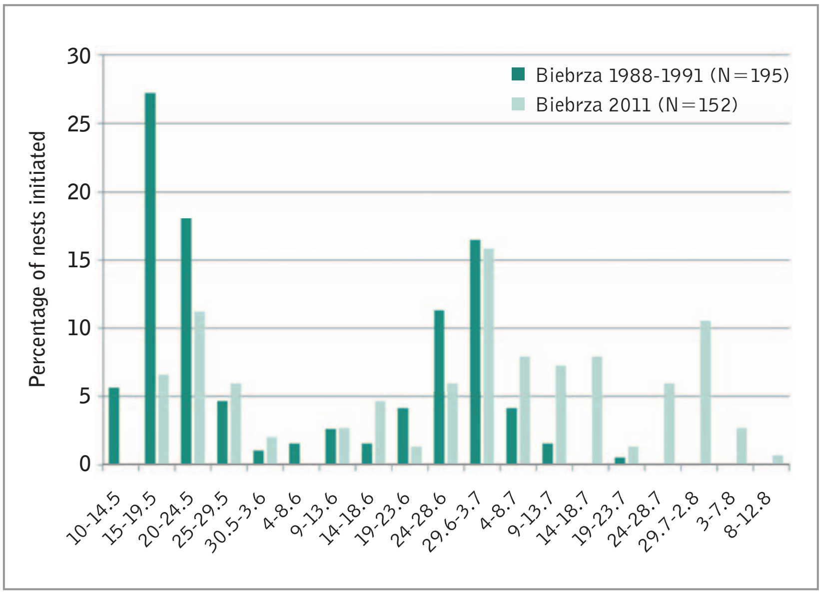
ANDRZEJ DYRCZ, ALEXANDER KOZULIN, LYUBOV VERGEICHIK & JUSTYNA KUBACKA

The Aquatic Warbler is unique in its promiscuous mating system (see below), combined with the fact that the female alone builds the nest, incubates eggs and feeds nestlings and fledglings. In contrast with other promiscuous species, however, the Aquatic Warbler lacks sexual dimorphism (see also Chapter 2.1) and a lek display system.

Timing of breeding

The birds arrive at their breeding grounds in central Europe between the end of April and the beginning of May. Males arrive, on average, slightly earlier than females. Most females, as shown by birds marked individually with colour rings in the Ławki Mire (Biebrza Marshes, Poland) in 1988-1991, complete two broods per season, thus creating two peaks of nest initiation dates. The first broods start in May to early June, and second broods are initiated in the second part of June and in July (**Fig. 2.5.1**). In the now extinct population at the Rietzer See in Brandenburg (Germany), which was studied between 1962-1974, the mean date of the first egg was 24 May for first broods, and 4 July for second broods. The earliest clutch dated from 10 May (Wawrzyniak & Sohns 1977). In the Ławki Mire in 1988-1991, the mean first egg dates were 18 May and 29 June for the first and second broods, respectively (the earliest clutch was initiated on 10 May; Dyrcz & Zdunek 1993a). In 2010-2012, it was 12 May and 28 June, with the earliest and the latest first egg dates on 7 May and 8 August, respectively (Kubacka et al. 2014). The late broods, observed in 2011, were most likely replacement clutches laid after many nests were flooded due to high precipitation in July (see **Box 2.5.1** and **Fig. 2.5.1**). For the Chełm Marshes (southeastern Poland), the mean firstegg dates in the first broods between 2012-2015 were about a week later than in the Biebrza Marshes (Kubacka & Wołoszkiewicz in prep.). The first and second broods in Belarus (1998-2005) were initiated on average on 21 May and 28 June, respectively (the earliest clutch on 6 May and the latest clutch on 22 July, **Fig. 2.5.2**; Vergeichik & Kozulin 2006b). It was shown that, when the nesting conditions are unfavourable, females can vary the timing of breeding quite freely within a long period from May to beginning of August, and in certain years all the females nest within a single short period (see **Box 2.5.1** and **Fig. 2.5.2**; Vergeichik & Kozulin 2006b).

▼ **Fig. 2.5.1**
Distribution of first egg dates of Aquatic Warblers in the Biebrza Marshes in 1988-1991 and in 2011, when high precipitation was observed in July (based on Dyrcz & Zdunek 1993a and Kubacka et al. 2014).



Nest location

The nest constitutes a small open cup placed on the ground, or low above the ground. It is constructed mainly with dry stems of vegetation, e.g. sedges. Five types of nest placement are distinguished: (1) under cover of dry lying sedge stems, invisible from above and typically on a tussock (**Fig. 2.5.3a** and **2.5.3b**), (2) on top of a tussock in dense, green vegetation (**Fig. 2.5.3c**), (3) in a rodent hole in a tussock, observed after early spring fires (**Fig. 2.5.3d**), (4) on dry sedge tangles, suspended above water (**Fig. 2.5.3e**), and (5) on the ground, where tussocks are not available and there is no water on the soil (Vergeichik & Kozulin

2006b, A. Dyrcz & W. Zdunek unpubl. data, J. Kubacka pers. comm.). In Belarus, 54.4% (N=191), and in Biebrza in 2010, 82.5% (N=56) of nests found belonged to the first type. The second type was usually found during the second broods and in the absence of the previous year's vegetation, when green vegetation was high enough to conceal the nest. Nests of the third type were found both in Belarus and the Biebrza Valley, and were usually built in May, in the absence of old vegetation and when the green vegetation was poorly developed. Nests suspended above water in the tangles of dry vegetation were found in Belarus (Vergeichik & Kozulin 2006b) and in Poland (Chełm Marshes; Kubacka & Wołoszkiewicz in prep.), when old vegetation was abundant and either the water level on the mire was higher than the firm part of the existing tussocks, or there were no tussocks (e.g. in a frequently mown habitat).

Thus, the species' ability to vary both the timing of breeding and nest placement could be considered as an adaptation mechanism to unstable nesting conditions of fen mires. However, it also becomes clear that there are certain site conditions that make it impossible for the Aquatic Warbler to place a nest, e.g. an absence of old or dense new vegetation, such as after a spring fire, or very high water levels combined with the absence of large tussocks and/or old vegetation. Faced with such conditions, females are assumed to move to nearby areas with better conditions, or to postpone the breeding attempt until the conditions improve (Vergeichik & Kozulin 2006b).

Box 2.5.1

Variation in nest initiation dates

LYUBOV VERGEICHIK, JUSTYNA KUBACKA, ANDRZEJ DYRCZ & ALEXANDER KOZULIN

Typically, most female Aquatic Warblers are double-brooded and there are two first-egg peaks within a breeding season, the first one towards the end of May and the second one at the end of June (**Fig. 2.5.1**). However, variation in nest initiation dates can be high. For example, at the Biebrza Marshes, in a year with high rainfall in July (2011; N=156 nests), which coincided with the second broods, flooding caused 67% of all the nest losses (Kubacka et al. 2014). Replacement clutches were laid, creating a third egg-laying peak at the end of July and the beginning of August, and the last egg-laying dates were unusually late (**Fig. 2.5.1**). Nest initiation dates in relation to changing conditions were also comprehensively studied at the largest sites in Belarus (Vergeichik & Kozulin 2006b, Vergeichik 2007). At the Dzikoje Mire (1999 and 2001, N=20 and 15 nests, respectively), habitat conditions were stable throughout the study period and the first-egg dates in the first breeding attempt followed the pattern found in the Biebrza Marshes, but only a few females laid second clutches, which is most probably because of a low-productivity habitat (**Fig. 2.5.2a**). At the Zvaniec Mire (1999, 2001, and 2003-2005; N=15, 21, 36, 32, and 16 nests, respectively), habitat conditions were extremely unstable and changed not only from year to year, but also within a breeding season. The timing of breeding in 1999 was typical of the species: the first clutch started in May or June, and the second one in July (**Fig. 2.5.2b**). The timing of breeding in 2001 and 2003-2004 did not significantly differ from the average laying dates, but a much higher number of females nested during the second clutch than in typical years (**Fig. 2.5.2c**), which was explained by better breeding conditions in July and a higher water level at the beginning of May. Due to a high water level in May, the first clutches in 2005 were laid relatively late, after the water table dropped, and during the second clutch in early July, only 13% of females initiated nests (**Fig. 2.5.2d**). At the Sporava Mire, in 1998 and 2000 the timing of breeding was typical; the first clutch started in May, the second one in late June 2000, and early July 1998, respectively (**Fig. 2.5.2e**). In May 2002, lack of spring flood, low water level and thick layer of dry biomass restricted the development of green vegetation and abundance of insects, and as a result, Aquatic Warblers nested in low density and only in May. In contrast, 2005 saw a high water level from April to mid June, caused by prolonged rains. Females started nesting immediately after the water level had decreased in mid-June, and egg-laying finished in mid-July (**Fig. 2.5.2f**). Overall, this high variation in the first-egg dates at the Belarusian mires was explained by fluctuations in water level and changes in vegetation composition due to fires and changes in water level (Vergeichik & Kozulin 2006b).

▲ **Fig. 2.5.2**

Distribution of first egg dates of Aquatic Warblers in the Dzikoje, Zvaniec, and Sporava mires in various years of study (based on Vergeichik 2007).

a)

b)

c)

▲ **Fig. 2.5.3a**

Typical placement of Aquatic Warbler nest under a roof of old sedges. Nest exposed for photography (photo: A. Baliński).

◄ **Fig. 2.5.3b**

Nest placement on tussock under a roof of dry reed stems in the Rozwarowo Marshes (photo: F. Tanneberger).

▲ **Fig. 2.5.3c**

Nest placement on top of a tussock under green vegetation only (photo: A. Kozulin).

2.5

► **Fig. 2.5.3d**

Nest placement in the hollow of a burned tussock (photo: V. Jurko).

▼ **Fig. 2.5.3e**

Nest placement above water in tangles of dry vegetation (photo: A. Kozulin).

d)

e)

Nest site characteristics

The nest is typically placed at a height of 12-18 cm (range 4-29 cm), with an average water depth of 0-9 cm (range 0-36 cm) Both show high variation and are likely related, so that nests are built higher as the water table rises within a season. The height of vegetation surrounding the nest is largely similar across various sites, averaging 82-98 cm, with a range of 55-142 cm. The thickness of litter, i.e. dry matter near the nest spans a broad range between habitats (7-71 cm), with a mean of 9-33 cm. Litter cover is always very high (**Table 2.5.1**). The nest site parameters are expected to vary by site, year, management, and the occurrence of fire events.

Breeding

Eggs are sub-elliptical, marbled deep olive-brown to light olive-brown (**Fig. 2.5.4**). The mean size is 17.8 x 13.1 mm (N=117; Wawrzyniak & Sohns 1977). One egg is laid per day. The clutch size is typically 4-5 eggs, with a range of 2-7 (**Table 2.5.2**, **Fig. 2.5.5**). In the Biebrza Marshes, clutches with 6 eggs occurred predominately during the first broods, while clutches with 3 and 4 eggs appeared mainly in second broods (Dyrcz & Zdunek 1993b). Typically, the clutch size is higher in the first than in the second brood (Dyrcz & Zdunek 1993b, Vergeichik & Kozulin 2006a, Knöfler 2012).

The incubation period is 14-16 days (Wawrzyniak & Sohns 1977, Dyrcz 1993). It is likely that real incubation starts from the penultimate egg, as one nestling (the runt) is usually clearly younger and smaller than its siblings. During the incubation, average nest attendance (11.1 min) and absence (5.1 min) periods are short – is among the shortest of all the Passeriformes studied in this respect (Dyrcz 1993), meaning that the female is usually coming and going all the time. In the 1988-1991 study in the Biebrza Marshes, it was found that 8.6% of eggs did not hatch, probably because they were not fertilised. This is a low figure in comparison to other species of the genus *Acrocephalus* (Dyrcz & Zdunek 1993b). In Belarus, the proportion of unhatched eggs in three different study areas amounted to 2.1%, 6.6% and 7.5% (total number of clutches: 165; Vergeichik 2007). Fledglings become independent 19-23 days after leaving the nest and attain their sexual maturity in the subsequent year (Schulze-Hagen 1991). In the Biebrza Marshes, the brooding activity of four females during the nestling feeding period was studied.

	Poland, Ławki Mire (N=63)	Poland, Chełm Marshes (N=26)	Lithuania (N=7)	Pomerania (N=3)
Nest height (cm)	13.3±5.0 (4-25)	18.4±10.5 (5-45)	12.4±9.3 (8-29)	-
Vegetation height (cm)	82.2±12.3 (55-110)	97.9±28.3 (42-155)	90.9±27.8 (60-142)	88.2±9.3
Litter height (cm)	26.2±8.7 (14-71)	33.4±13.6 (7-71)	14.2±6.2 (8-26)	9.4±4.1
Soil moisture (class 1-6)	-	-	3.5±0.8 (3-5)	-
Water depth (cm)	4.8±2.9 (0-14)	9.0±8.0 (0-36)	0.0±0.0 -	0 -
Cover of lower herb layer (%)	-	-	11.5±11.3 (1-30)	25±21 -
Cover of upper herb layer (%)	-	-	88.3±4.1 (80-90)	75±21 -
Cover of litter layer (%)	-	97.0±8.1 (63-88)*	96.7±5.7 (90-100)	-
Species number	-	-	5.3±2.6 (3-11)	-

* litter cover assigned to a class between 0 (no cover) and 1-4 (1-24, 25-49, 50-74, and 75-100%)

◄ **Table 2.5.1**
Aquatic Warbler nest site characteristics from various sites during first broods. Means±standard deviations are given, with range underneath. N = sample size. Source: Kubacka & Wołoszkiewicz in prep. (Poland, 2012: Ławki Mire and 2014: Chełm Marshes), Knöfler 2012 (Lithuania, 2011), and Tanneberger et al. 2013 (Pomerania, 2006).

Fig. 2.5.4
Aquatic Warbler nest with complete clutch (photo: P. Castell).

When the nestlings were two days old, the females devoted on average 52.9% of their time to brooding. This proportion of time became progressively shorter over the following days, with only 27.8% of time spent brooding seven-day-old nestlings. Older nestlings were brooded only sporadically (1.2-3.4% of time). Females feeding nestlings did not fly far from the nest, usually 25-30 m (see Chapter 2.4). The foraging grounds of feeding females did not overlap much with those from neighbouring nests (Dyrcz & Zdunek 1993a).

Individually colour-ringed males sang with roughly unchanged intensity until the end of the season. This is obviously connected with their promiscuous mating system. Daily singing activity (number of songs per time unit) also differs from most other Passeriformes. The maximum song activity occurs just before and after sunset (Dyrcz & Zdunek 1993a). According to a radio-tracking study by Schaefer et al. (2000), males have home ranges of up to 8 ha. These home ranges overlapped by up to 74% (mean 51%) between individuals. In the Aquatic Warbler, no violent territorial clashes between males were observed. However, according to Catchpole & Leisler (1989), one of the three main song types of the Aquatic Warbler is used as a short-range aggressive signal (see also Chapter 2.6).

Table 2.5.2
The clutch size of the Aquatic Warbler at important breeding sites.

	Biebrza Marshes, Poland	Biebrza Marshes, Poland	Chełm Marshes, Poland	Dzikoje, Belarus	Zvaniec, Belarus	Sporava, Belarus	Nemunas Delta, Lithuania
Years of study	1988-1991	2012	2013-2014	1999, 2001	1999, 2001, 2003, 2004	1998, 2000	2011
Mean ±s.d. 1st broods	5.11±0.60	5.09±0.67	5.05±0.62	4.68±0.82	4.86±0.69	5.00±0.95	5.57±0.53
Mean ±s.d. 2nd broods	4.37±0.60	4.53±0.76	3.90±0.88	-	4.24±0.73	4.69±0.85	4.75±0.46
Range	3-6	2-6	2-6	3-6	3-7	2-6	4-6
Sample size	157	55 *	29 *	28	99	34	15
Source	Dyrcz & Zdunek 1993b	Kubacka & Wołoszkiewicz in prep.	Kubacka & Wołoszkiewicz in prep.	Vergeichik & Kozulin 2006a	Vergeichik & Kozulin 2006a	Vergeichik & Kozulin 2006a	Knöfler 2012

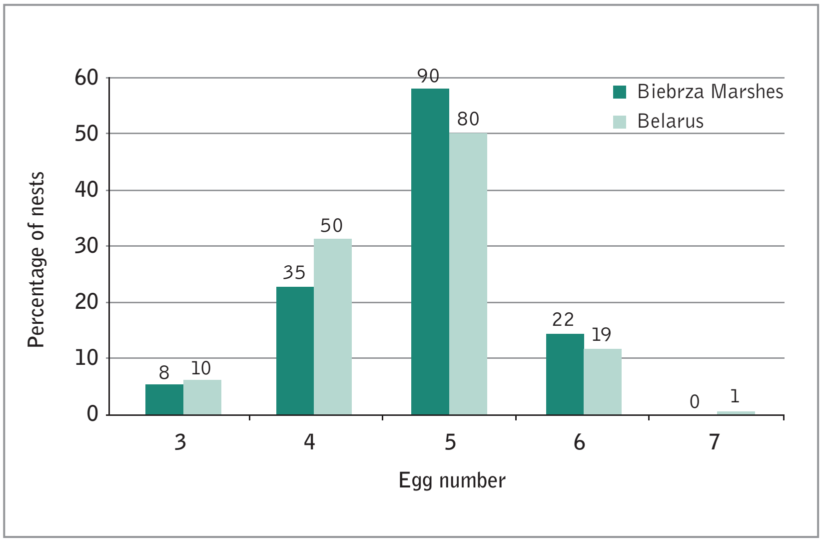
* only nests found at the incubation stage

Breeding density

For practical reasons, the size of breeding populations of the Aquatic Warbler is usually determined by the number of singing males. This is because the number of breeding females is much more difficult to ascertain. It was shown that the number of singing males is a reliable indicator of nest densities (Kubacka et al. 2014). However, it is the number of females that controls the reproduction rate of a population. Therefore, to determine the absolute numbers of the Aquatic Warbler, it is important to know either the nest density or the proportion of males to females in a population. Both can vary to a large extent and our knowledge concerning these parameters is still not sufficient, as only a few populations have been studied in this respect and detection probability is not equal between the two sexes (see Chapter 2.7).

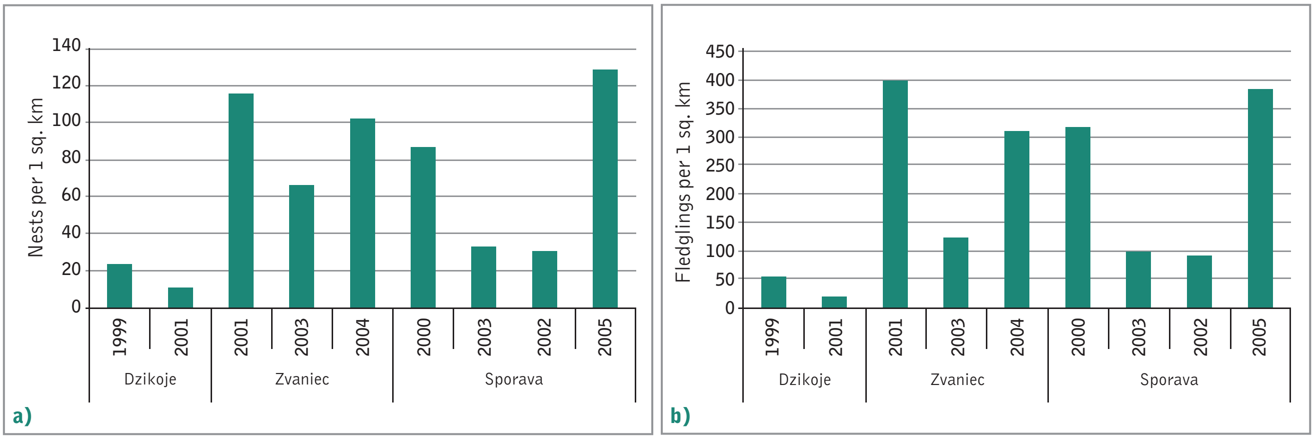
The density of birds on a 44 ha sample plot in the Ławki Mire in different years and periods ranged from 5.0 to 10.9 males per 10 ha and 1.4 to 9.8 females per 10 ha (Dyrcz & Zdunek 1993a). In 2010-2012, on a number of study areas in the same location, from 1.8 to 21.5 (mean 9.6) males per 10 ha were observed and from 0.0 to 18.0 (mean 6.0) nests per 10 ha were found (Kubacka et al. 2014, see also **Box 2.5.2**). In Belarus, the densities of males and females in different places, years, and periods varied from 1.5 to 13.7 males per 10 ha and from 0 to 12.8 females per 10 ha (Vergeichik & Kozulin 2006a). Density of nests and males varied also by mire type and was the lowest on the poor mesotrophic mire (**Fig. 2.5.6a** and **2.5.6b**; Vergeichik 2007). Under non-uniform breeding conditions, higher densities of Aquatic Warblers nests were found on plots with a higher productivity of vegetation and more favourable conditions (Dyrcz & Zdunek 1993a, Vergeichik & Kozulin 2006a).

The density of males and nests can vary considerably between the early and late nesting periods. Both were often found to be higher during the first broods than during the second broods, but this was not always the case, even within the same sites (Dyrcz & Zdunek 1993b, Vergeichik & Kozulin 2006a, b, Kubacka et al. 2014). Generally, it is temporal variation in vegetation development and water level that determines whether it is early or late nesting periods that show higher densities. Male density during the later period is usually higher in the years when nesting conditions are unfavourable at the beginning of the breeding season (Kozulin & Vergeichik 2006). In addition, Aquatic Warbler males are able to move to more favourable breeding places any time from May to early June (Kozulin et al. 1999, Wawrzyniak & Sohns 1977). Therefore, a deterioration in conditions during the breeding season (rising water level) leads either to a redistribution of birds to undisturbed parts of the same mire (Zvaniec 1999, 2003, 2005), or to the abandonment of the unsuitable mire and the migration of birds to other mires (Jasielda river flood-plain, 1998, 1999, 2002) (Kozulin & Flade 1999, Kozulin et al. 2004, Kozulin & Vergeichik 2006). For example, in Pomerania (Poland), Aquatic Warbler numbers at Karsiborska Kępa were higher in the early season, while the opposite held at the nearby Rozwarowo Marshes and in other Pomeranian breeding sites. There is also evidence of a colour-ringed male using Karsiborska Kępa during the early part of the season and Rozwarowo during the later part (G. Kiljan unpubl. data).



▲ **Fig. 2.5.5**
Distribution of the clutch size of Aquatic Warblers in the Biebrza Marshes in Poland and on mires in Belarus (from Dyrcz & Zdunek 1993b and Vergeichik 2007). **Numbers above the bars indicate the number of nests with a given egg number.**

2.5



▲ **Fig. 2.5.6**

Density of Aquatic Warbler nests a) and area productivity b) in Belarusian mires (Vergeichik 2007). **Dzikoje is the most nutrient-poor of the three sites.**

Nest survival and breeding success

How many young in a nest survive to fledging (breeding success) depends primarily on nest survival (nesting success). The latter can be calculated using the traditional method (which assumes that nesting is successful if at least one fledgling leaves the nest) or using the Mayfield method (which accounts for the fact that some failed nests may have been missed and is based on daily nest survival rates; Mayfield 1975). It has been shown by various studies that the Mayfield method is more accurate for calculating the Aquatic Warbler's nesting success than the traditional method. In the Biebrza Marshes in Poland (Ławki Mire), between 1988 and 1993, the nesting success (N=189 nests) calculated using the Mayfield method was between 60 to 67% (62.7% on average; Dyrcz & Zdunek 1993b). Nest losses were caused mainly by predators (11.1% of all the detected nests on average), as is the case in most studied passerine species (Newton 1998), and predation pressure fluctuated significantly, but irregularly with time and place (A. Dyrcz unpubl. data). Another reason for nest losses was flooding, though this occurred only in one year of study, causing 6.7% of the detected nests to be lost in that year, compared with 12% of predated nests (Dyrcz & Zdunek 1993b). The average number of fledglings produced per nest was (mean±s.d.) 3.80±1.77 in the first brood and 2.33±1.76 in the second brood; the average number of fledged young per successful nest was 4.38±1.03 and 3.31±1.40, respectively (N=157). This breeding success is higher than in some related marsh nesting species of the genera *Acrocephalus* and *Locustella* (Dyrcz & Zdunek 1993b).

The study carried out in the Ławki Mire between 2010 and 2012 (N=364 nests; Kubacka et al. 2014), in which the nesting success was calculated using the programme MARK (based on a similar principle as the Mayfield method, but applying the maximum likelihood for estimation), found a comparable nest survival rate (**Box 2.5.2**), number of fledglings per nest (3.50±1.82 in the first, and 2.76±1.95 in the second broods), and number of fledglings per successful nest (4.20±1.05 and 3.86±1.04, respectively). Nest losses were mostly caused by predation (16.1% on average) and flooding (9.69% on average), with the latter occurring in two out of the three years of study. In a year with especially high precipitation at the time of second broods, a majority of losses (23.7%, compared to 8.3% predated nests) were due to flooding (based on Kubacka et al. 2014; see also **Box 2.5.1** and **Fig. 2.5.1**). Data from these two studies (Dyrcz & Zdunek 1993b, Kubacka et al. 2014) were pooled together to assess whether nest survival and fledged brood size had changed over the two decades, for instance as a result of inbreeding depression or habitat management, but no decadal effect was found (Kubacka et al. 2014; **Box 2.5.2**, **Fig. 2.5.8a** and **2.5.8b**).

In 1998-2004, the breeding ecology of the Aquatic Warbler was studied at the three largest mires in Belarus (Dzikoje, Sporava, and Zvaniec, see Chapter 2.2; Vergeichik & Kozulin 2006b). The mires differ in the amount of nutrients, microrelief, vegetation, and hydrological regime. The nesting success of 161 nests was calculated using the Mayfield method. It varied considerably, from 2.9% to 54.1%, between years, depending on habitat conditions (N=161 nests; Vergeichik & Kozulin 2006a). The main reasons for nest losses were the rise of water level during the breeding season and predation. The importance of these factors varied between the mires. Flooding was the main cause of losses at the Sporava Mire, which has flat terrain, while nest losses in the Dzikoje and Zvaniec mires were mainly due to predation. Predation pressure increased with the density of predators on the mire and was also higher under suboptimal conditions (such as a higher water table, immature green vegetation, or a lack of the previous year's vegetation), and when nests were placed in an unusual way and more visible to predators. The main predators of Aquatic Warbler nests at the Belarusian mires were shrews (Vergeichik & Kozulin 2006a). Overall, in the years with favourable nesting conditions, the nesting success on the three mires varied from 36.3% to 54.1%. These estimates are similar to those observed in other ground-nesters, such as the Meadow Pipit *Anthus pratensis* (44.9%), the Thrush Nightingale *Luscinia luscinia* (43.0%), and the Yellow Wagtail *Motacilla flava* (38.4%) (Payevskiy 1985). By contrast, in the years with water level fluctuations and shrew outbreaks, the nesting success decreased abruptly and ranged from 2.9% to 27.7%. It was higher than the Belarusian mean (28.9%) in five out of the eight seasons of study, and lower during the other three. The number of fledglings produced per nest (average for each of the three mires) ranged from 2.46 to 4.00 for the first brood, and from 1.38 to 3.44 for the second brood, and the number of fledglings produced per successful nest was 2.65-4.18 for the first brood, and 3.00-3.92 for the second brood (N=161). The average number of fledglings per nest in Belarus was 3.20 and 3.99, per nest and per successful nest, respectively (Vergeichik &

Box 2.5.2

Mowing and breeding productivity of the Aquatic Warbler in the Biebrza Marshes, Poland

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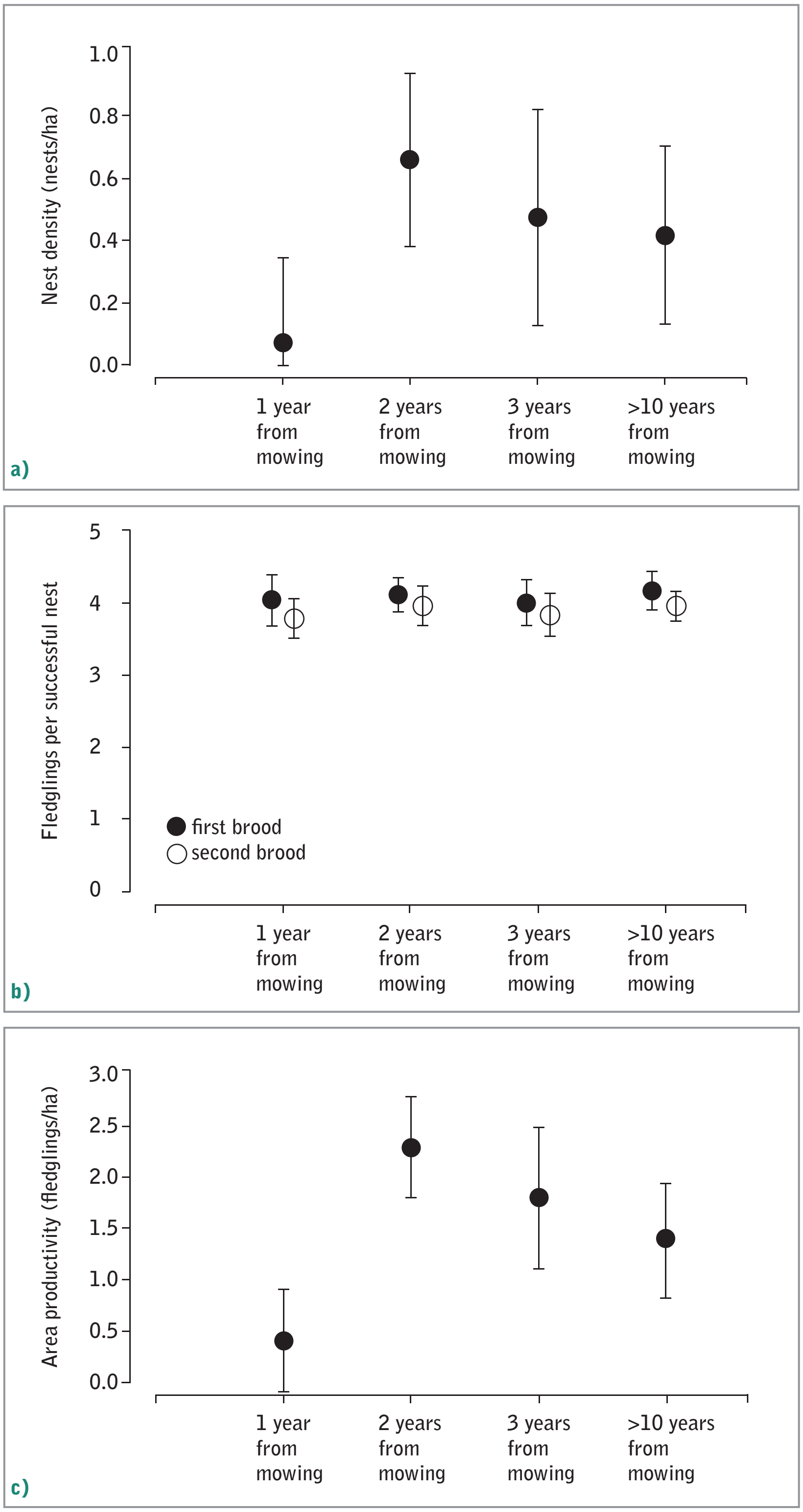
Aquatic Warblers nest in a narrow range of open habitats with grassy vegetation and generally wet ground. A high water table limits access to the marsh for terrestrial predators, and the species has high nest success rates compared to other open-cup nesting songbirds (Dyrcz & Zdunek 1993b). Because it is increasingly dependent on habitats that are managed to reduce natural succession towards bushy and thus less suitable habitat, we investigated whether the area breeding productivity (number of fledglings per area unit) as well as its components: nest density, nest survival, and fledged brood size were similar between the managed and naturally open fen mires (Kubacka et al. 2014). From May through August 2010-2012, we followed the fate of 364 nests located in the Biebrza National Park, Poland. The study plots were located in areas of the mire that had either been recently mown or had not received any management intervention for at least 10 years but were still suitable for Aquatic Warblers.

The results showed that nest density was affected by mowing: it was very low one year after mowing, peaked the following year and declined afterwards. On average, it did not appear to differ from the nest density in unmanaged areas (**Fig. 2.5.7a**). The average number of fledglings per successful nest was 4.0 (95% confidence interval 3.8-4.1) and ranged from one to six fledglings. The fledged brood size did not differ between the different temporal stages after mowing (**Fig. 2.5.7b**). The nest survival was quantified accounting for the fact that the nests were found at different stages, and that some failed nests may have been missed, using the programme MARK and an information-theoretic approach. The estimated nest survival in our study area was 0.62 (95% confidence interval, CI: 0.48-0.73) and varied substantially between years, ranging from 0.49 (95% CI 0.36-0.61) in 2011 to 0.79 (95% CI 0.66-0.87) in 2012. Daily nest survival probability varied between years and declined over the breeding season, as well as with the increasing age of the nest. A weak effect of nest initiation date on daily nest survival was found, with slightly higher survival in the first broods. The effect of vegetation height, water depth and litter thickness was of even lower significance. Daily nest survival was not affected by the temporal stage of the habitat after mowing. The final area productivity followed the same pattern as nest density, being clearly the lowest in the breeding season after an autumn or winter mowing, growing to high numbers in the following year, and decreasing afterwards (**Fig. 2.5.7c**). The fledged brood size of successful nests and nest survival probability were compared between a historic period (1988-1991), using data analysed by Dyrcz & Zdunek (1993b) and our study period. There was no evidence for a systematic decline in these breeding productivity variables between the two periods (**Fig. 2.5.8a**, **2.5.8b**).

These findings indicate that the effect of mowing on the productivity of the Aquatic Warbler is mediated through nest density and not through nest survival. In addition, in a mesotrophic habitat (such as ►

2.5

Box 2.5.2 contd the one in the Biebrza Marshes), mowing should only be applied if substantial succession occurs, and not more often than every second year, in order to allow vegetation recovery and to compensate for the negative effect on nest-densities (Kubacka et al. 2014).



Kozulin 2006a). It was also found that the density of nests and the number of fledglings per nest of the Aquatic Warbler was explained by the amount of nutrients at the site and was higher in rich, eutrophic mires (99-400 fledglings per 100 ha per year) than in the poor, mesotrophic mire (18-54 fledglings per 100 ha per year), despite high variation between the years (**Fig. 2.5.6**, Kozulin & Vergeichik 2006, Vergeichik 2007).

Mating system

The mating system of the Aquatic Warbler was understood only relatively recently, and some details are still not clear. As the first researcher to suspect the existence of promiscuity, Heise (1963, 1970b) carried out a pioneer study on this species in Brandenburg (Germany). In 1980, based on observations of an individually colour-ringed population in Biebrza, polygyny was also suspected (Dyrcz 1989). However, it was only the application of molecular methods for genetic analysis (Schulze-Hagen et al. 1993, Dyrcz et al. 2002) that brought final clarity to this question. Of 64 broods studied in 1993, 1994, and 1997 in the Biebrza National Park, 14 broods were sired by a single male, but 50 (78.1%) by two or more males. A maximum of five fathers was detected in four broods. The frequency of multiple paternity varied between years (from 54.5 to 92.3%) (Dyrcz et al. 2002). The number of nestlings sired by an individual male ranged from one to eight. Reproductive success among males was uneven, with six males (18%) fathering 44% of all nestlings in the study area. The number of nestlings sired by a male correlated positively with its fat deposits and wing length, and negatively with the date of the first egg. The number of sired offspring was lower in males infected with blood parasites (trypanosomes), increased with

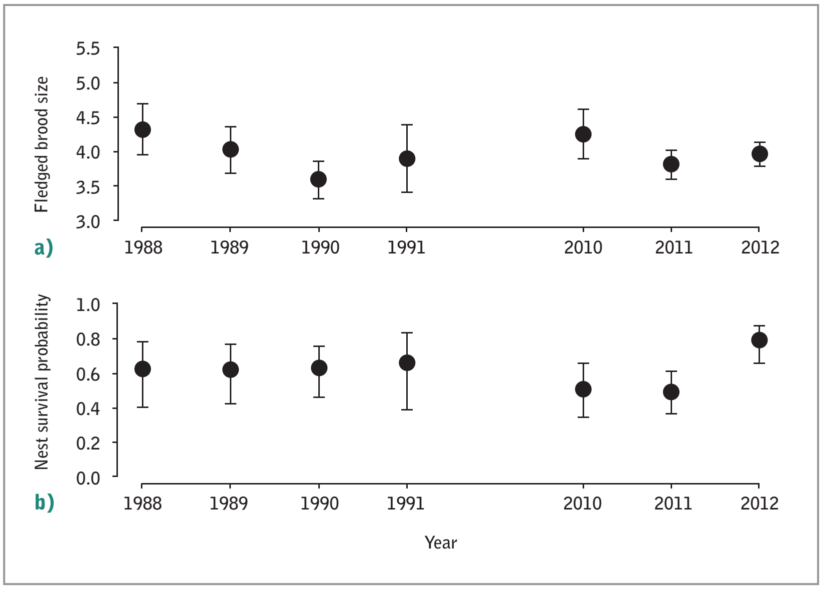
◄ **Fig. 2.5.7**

Effects of mowing on a) nest density, b) fledged brood size of successful nests, and c) area productivity. Means predicted by models ± 95% confidence intervals are shown (based on Kubacka et al. 2014, copyright Bird Conservation International 2014).

fat deposits and wing length of the male, and decreased with the date of the first egg (i.e. the males that arrived later to breeding grounds probably sired fewer young; Dyrcz et al. 2005). In hand-reared, captive birds, the mean duration of mounting during copulation was 23.7 min. On average, six cloacal contacts (inseminations) occurred during each copulation. By contrast, in most bird species, a single copulation lasts only a few seconds. Male Aquatic Warblers also exhibit extreme morphological adaptations to their reproductive system: compared to other *Acrocephalus* species and other birds, their testes, cloacal protuberance, and seminal glomera are all very large in relation to body size (Schulze-Hagen et al. 1995). The Aquatic Warbler mating system constitutes a textbook example of what is known as 'sperm competition'. Males do not defend territories, and competition with other males is restricted to the amount of spermatozoa deposited in females' reproductive tracts. Frequent insemination during protracted copulation and contact mate guarding practised by the Aquatic Warbler may be alternatives to paternity guarding found in other birds.

According to Kozulin et al. (1999) and Leisler et al. (2002), the Aquatic Warbler mating system evolved as an adaptation to life in a changeable but very food-rich habitat. Examples of changing factors are variations in water level in the mire during the breeding period and spring burning of vegetation due to lightning strikes. At the same time, an unusual (though temporary) richness of potential food in fen mires allows uniparental care of the young. Feeding females usually find enough food close to the nest. The species is thereby able to breed semi-colonially to make the best use of rich food supplies, and, in places where nests were grouped, food (insects and spiders) is more abundant than at isolated nests (Dyrcz & Zdunek 1993a).

The Aquatic Warbler's unique reproductive system therefore allows the species to shift the timing of breeding and also to be able to move to more favourable breeding places during the breeding period. This is facilitated by the lack of social bonds between sexes, and by the lack of strict territorialism (Wawrzyniak & Sohns 1977, Schulze-Hagen 1991, Kozulin et al. 1999, Schulze-Hagen et al. 1999).



▲ **Fig. 2.5.8**

Comparison of a) fledged brood size of successful nests and b) nest survival probability of Aquatic Warblers in the Biebrza Valley between a historic (1988-1991) and a current (2010-2012) period. Means±95% confidence intervals are shown (from Kubacka et al. 2014, copyright Bird Conservation International 2014).

2.6 Voice and song behaviour

JAKUB GLAPAN

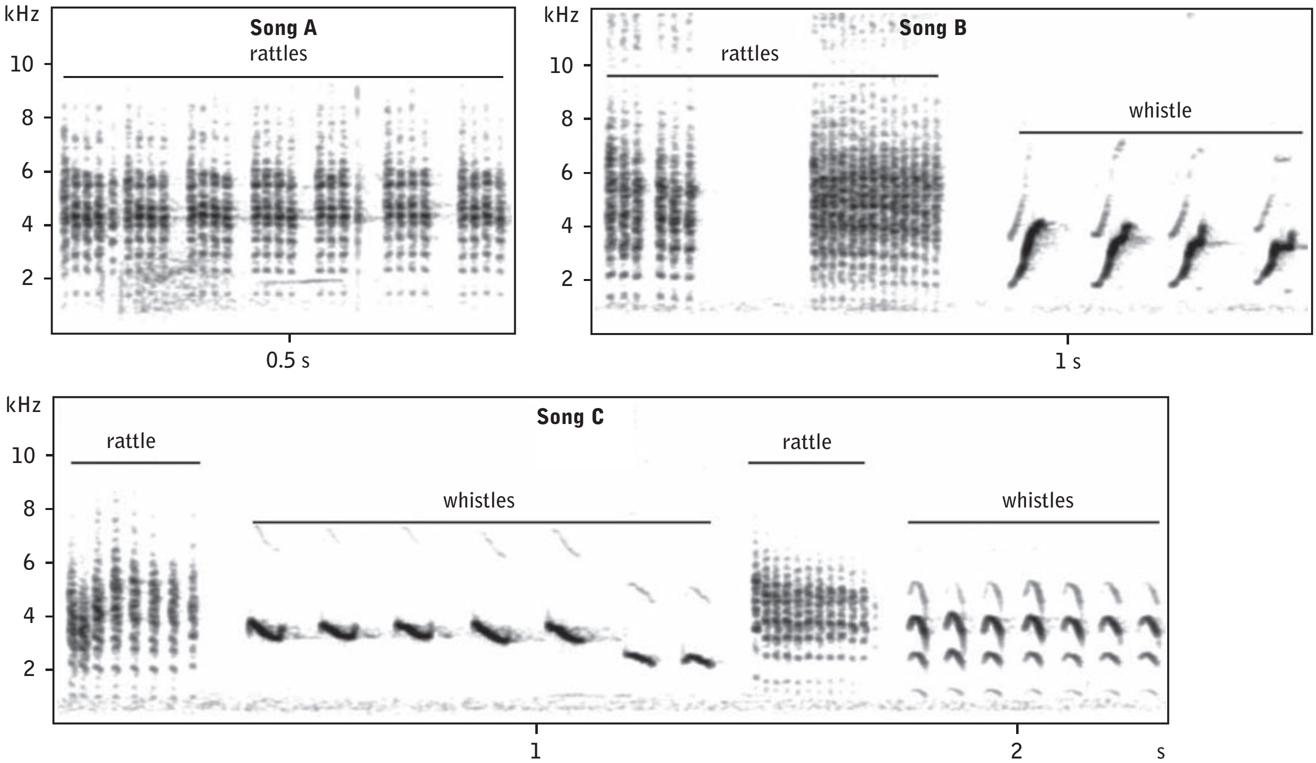
In birds, vocalisations are used in territorial defence, mate attraction, and communication with conspecifics (e.g. alarm calls). The most distinctive of bird vocalisations is the song, which can significantly affect male reproductive success (Bradbury & Vehrencamp 1998). Since Darwin it has been well known that birdsong is a sexually selected trait and plays a role in intra-sexual as well as inter-sexual communication. In many bird species, females choose males based on the characteristics of their songs (Nowicki & Searcy 2004). For example, females prefer to mate with males that have large repertoires (Common Nightingale *Luscinia megarhynchos*; Kipper et al. 2006), complex songs (Great Reed Warbler *Acrocephalus arundinaceus*; Catchpole 1983) or acoustic 'ornaments' in the repertoire, such as the 'sexy syllables' in canaries (Leitner & Catchpole 2004).

Song behaviour

The Aquatic Warbler belongs to the *Acrocephalus* genus, in which almost the whole spectrum of possible mating systems has been described (Leisler & Schulze-Hagen 2011). It has a mating system intermediate between promiscuity and polygyny, with high rates of multiple paternity within broods (Birkhead 1993, Dyrcz et al. 2002; see also Chapter 2.5). Mating systems may have a strong influence on the accompanying acoustic communication. In many bird species, singing activity decreases after forming pair bonds. Aquatic Warblers, however, do not form pairs and most females engage in a second brood, increasing the probability of finding a suitable mating partner by high mobility (with mean activity ranges of 120 ha during the mating period; Schaefer et al. 2000). A consequence of this behaviour is that male singing activity (**Fig. 2.6.2**) is almost constant during the mating season (Dyrcz & Zdunek 1993a, Schmidt et al. 1999). Aquatic Warblers copulate in the first and last hours of daylight (Schulze-Hagen et al. 1995), and song activity is the highest around sunset, when males participate in the evening chorus, but also in the early morning (Dyrcz & Zdunek 1993a). With regard to habitat used for singing, latest research shows that males select green plants as song posts in habitat patches with tall vegetation and a low water level, and use relatively higher song posts in comparison with the total plant height (Grzywaczewski et al. 2014).

Song structure

In the Aquatic Warbler, the structure of the song is built by whistles and rattles (**Fig. 2.6.1**), and, as in other *Acrocephalus* species, two types of song structures are distinguished – long, complex and variable songs for mate attraction (intersexual selection), and simple, short songs for territorial defence (intrasexual selection; Catchpole 1983). Catchpole and Leisler (1989, 1996) classified three types of song in terms of length and complexity. The A-song is short and consists of a single phrase (**Fig. 2.6.1**). Males produce an A-song as an aggressive signal during the invasion of a rival male. B- and C-songs are longer and more complex (**Fig. 2.6.1**). Males produce the B- and C-songs as spontaneous songs, but the longest and more complicated C-songs are used for female attraction (and are produced also during the flight song).



▲ **Fig. 2.6.1** **Sonograms showing the structure of Aquatic Warbler songs.**

Geographical variation in song

Song variation at the population level may be used as an 'early-warning indicator of perturbations' in populations (Laiolo 2010). The Aquatic Warbler is a habitat specialist and many breeding sites are used for low-intensity agriculture (Tanneberger et al. 2005; see also Chapter 2.3). Factors such as habitat fragmentation may change acoustic behaviour. In fragmented habitats, animals become restricted to smaller local populations and this decreases the diversity of the pools of syllables and song types (cultural erosion; Bender et al. 1998, Laiolo & Tella 2007).

The song of the Aquatic Warbler was recorded in several subpopulations and over a broad period, forming an extensive collection (**Table 2.6.1**). Glapan (2013) was the first to comprehensively describe the geographical variation of Aquatic Warbler song. Songs for the purposes of this analysis were recorded in 2008-2011 in four geographically and ecologically distinct subpopulations (**Table 2.6.2**). Song variation was studied at several levels: repertoire size and quality, temporal organisation of song, syntax, and spectral parameters. The study found differences in song temporal organisation and syntax between the subpopulations, which may have a genetic basis. The subpopulations also varied in terms of song spectral parameters, which can be explained by habitat differences. Analysis of song syllable repertoires showed that in the two large and stable subpopulations, in the Biebrza National Park and in Belarus, males sing more distinctive song phrases (called dialects), relative to other studied populations. Dialect variation was found in C-songs and was reflected by sharing repertoire of whistles (directed to females). The highest variation in syllable types between males was found in the Pomeranian subpopulation. In this case song likely reflects its fragmentation and instability.

Future studies should combine song research with genetic and habitat sampling, for a better explanation of the relationship between song and the environmental as well as genetic characteristics of populations (see also Chapter 6).

2.6

Alarm vocalisations

When an intruder is close to the nest, the female utters distinctive alarm calls ('tack'), sometimes followed by a trill-like 'cherr-cherr'. These alarm calls are sometimes also produced by males, plausibly close to a nest in which the male fathers young (J. Kubacka pers. comm.). Although males do not take an active part in breeding, it was regularly observed that, in the presence of an observer by the nest, they produce a modified song and alarm call, which may have an anti-predator function (Dyrcz et al. 2011).

► **Table 2.6.1**
Recordings of Aquatic Warbler song collected in 1971-2010.

Country	Site(s)	Year(s)	Males	Recordings	Person
Belarus	Sporava	2008	29	29	J. Glapan, M. Dmitrenok
	Zvaniec and Sporava	2010	28	28	M. Dmitrenok, A. Wiśniewska
Hungary	Hortobágy National Park	1971 2000 2001 2003 2005	44	44	A. Schmidt, Z. Végvári
		2009-2010	16	16	J. Glapan, L. Turcokova
Lithuania	Nemunas Delta	2006	over 8	4	F. Tanneberger
Poland	Biebrza National Park	1993, 1995	31	31	A. Dyrcz
		1997	53	952	V. Schaefer
		2008	10	10	A. Wiśniewska
		2010	47	47	J. Glapan
Poland/ Germany	Pomerania	2004-2007	over 42	51	F. Tanneberger, J. Glapan
		2007-2010	33	33	J. Glapan

► **Table 2.6.2**
Recordings used to describe the geographical variation of Aquatic Warbler song (Glapan 2013)**. Good quality recordings were without noises.**

Country and population	Site	Year	Number of recordings	
			All	Good quality
Poland, Biebrza National Park	Bagno Ławki	2008	7	6
	Bagno Podlaskie	2010	29	22
		2011	25	25
Total			61	53
Poland, Pomerania	Karsiborska Kępa	2009	11	7
	Rozwarowo	2010	7	4
	Krajnik			
Total			18	11
Belarus	Sporava: Kasciuki	2008	17	17
	Sporava: Piasčanka			
Total			17	17
Hungary	Hortobágy	2009	6	6
		2010	4	2
Total			10	8
Grand total			106	89

▲ **Fig. 2.6.2**
Male Aquatic Warbler. (photo: Ž. Morkvėnas)

2.7 Population dynamics

JOCHEN BELLEBAUM

The long-term development of the Aquatic Warbler world population is largely unknown, although a substantial decline can be concluded from the large-scale range loss in the 20th century in Europe (e.g. Briedis & Keišs 2016) and probably also in Siberia. In contrast, the fluctuations in several local populations are well documented, mainly from counts of singing males (see Chapter 2.2). To successfully conserve the remaining populations it is necessary to take into account key population processes, such as breeding productivity and survival (see Chapter 2.5). These processes are essential for understanding the dynamics of breeding populations and for properly assessing their ability to survive or expand.

Survival and sex ratio

The first estimates of adult survival for the core breeding site in the Biebrza Valley show that apparent survival rates, especially of males, can be as high as 0.67 (see **Box 2.7.1**). Estimates for females were lower. Since apparent survival is the probability that a bird survives and returns to the study population, it is uncertain if females show a lower survival or lower site fidelity. Both processes were observed in small passerines (Clarke et al. 1997, Payevsky et al. 1997) and Aquatic Warbler females might be especially prone to reduced survival, as they carry all the costs of incubation and chick rearing.

Lower female survival is suggested by some studies on adult sex ratio. The primary sex ratio of the Aquatic Warbler is balanced, i.e. half of the nestlings are males, as the overall sex ratio determined by molecular sexing of nestlings at 8-11 days of age (N=63 broods) did not deviate significantly from parity (proportion of females 0.509; Dyrcz et al. 2004). In contrast, some field studies suggest that in many breeding sites the number of singing males is higher than that of breeding females (see Chapter 2.5). On study plots in the Biebrza Valley, Dyrcz & Zdunek (1993a) found that on average 56% of the adult birds were males, which is very close to the proportion of 55% observed in the Rietzer See breeding site (Brandenburg, Germany) in 1969-1970, before this population declined and finally went extinct (Sohns & Wawrzyniak 1973, Wawrzyniak & Sohns 1977, and unpubl. data; **Fig.2.7.1**). In the latter population, during 1969-1974 in all but one year the number of males clearly exceeded that of females. However, during the breeding season male Aquatic Warblers are much easier to detect than females (see also **Box 2.7.2**). Males sing and display conspicuously throughout the season, whereas females are cryptic and best located through nest search. Even if nests are searched for regularly throughout the breeding cycle, some females will still go unnoticed, especially in dense habitats. Therefore, in the Aquatic Warbler the number of breeding females could easily be underestimated.

Even higher values of 68-70% males were found in two rapidly declining populations at the Rietzer See 1971-1973 (**Fig. 2.7.1**) and on Karsiborska Kępa 2001-2003 (G. Kiljan unpubl. data). Such a heavily skewed sex ratio should be expected in a local breeding population with apparent male survival of 0.67, apparent female survival of 0.42, and no immigration. In contrast, a balanced sex ratio of 54% males was found among 59 Aquatic Warblers caught in winter in Africa using genetic markers (Vogel 2009). Since these birds had already completed their moult, the number of adult and young birds in this sample remains unknown. At any rate, the scenario of sex-bias in survival rate could not explain the balanced proportion of sexes found in Africa. In order to reach this in winter, including the young of the previous year for which we might expect a balanced sex ratio, the actual female survival should be at least 0.57, or even higher. Hence, if the observed sex ratios are correct, the apparent survival estimate of 0.42 for females includes a substantial degree of dispersal, as could be expected because, among songbirds, females are usually the less site-faithful sex (Clarke et al. 1997). In small, isolated populations, such as the one in Pomerania, this might increase the risk of extinction (Dale 2001).

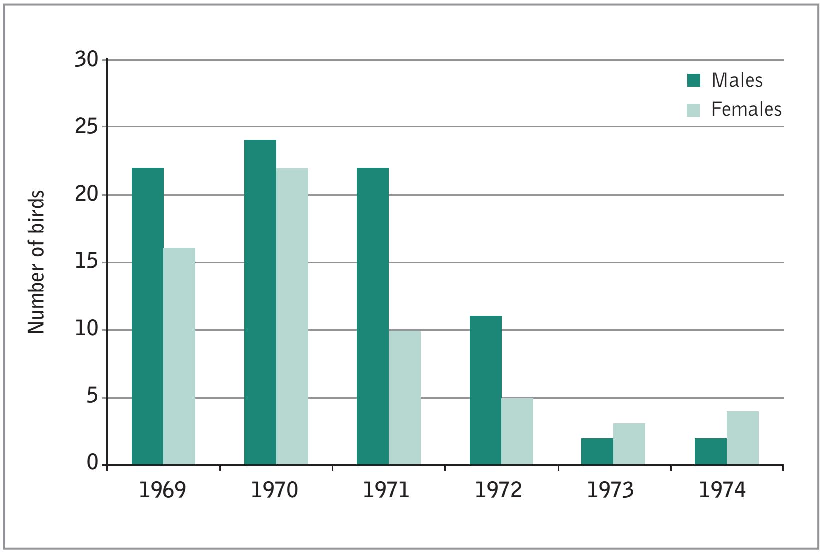
Assuming that the actual female survival is 0.57 and further assuming first year survival to be 0.37, according to the published estimates for other warblers (Peach et al. 1990, Peach et al. 1991, Foppen et al. 1999, Thaxter et al. 2006), an average productivity of 2.3 young per female per year would be required for a stable breeding population. This is below the average output of a single breeding attempt in high-quality habitats (see Chapter 2.5). Despite the remaining uncertainties about true survival rates we can conclude that Aquatic Warbler populations should be able to survive years with low breeding success and to quickly increase under optimal conditions. Stable populations might also exist where only a single brood meets favourable conditions, but in these cases, populations are likely to be very susceptible to years with unfavourable conditions. At the other extreme, in a local population where apparent female survival is 0.42 and dispersal is not balanced by immigration, e.g. because of isolation or low habitat quality, the required productivity would be more than 3.1 young per female per year. A second breeding attempt would probably be needed here. Immigration and emigration data is clearly important to understand the dynamics of local populations. Colour ringing in Poland revealed the occurrence of between-site movements in the Lublin region (Foucher et al. in prep.) and Pomerania (see below), but unfortunately there is little information about the frequency of such movements.

Box 2.7.1

Adult survival of Aquatic Warblers breeding in the Biebrza Marshes, Poland

ANDRZEJ DYRCZ & PRZEMYSŁAW CHYLARECKI

Annual survival of Aquatic Warblers long remained a mystery, impairing our ability to model the species' demography. The survival of adult Aquatic Warblers was estimated in the Biebrza Marshes, a rather stable and abundant population forming the core of the Polish range of the species (see Chapter 2.2). In 1987-1995, 279 breeders from the population in the Ławki Mire in the Biebrza National Park were ringed (149 males and 130 females; see Dyrcz & Zdunek 1993a for more details of the study site). The data were analysed with capture-mark-recapture models, using MARK 5.1 software (White & Burnham 1999). These models estimate apparent survival, i.e. the probability that a bird survives and returns to the study area, together with the probability that a returning bird is actually detected in a given year. The model assuming that apparent survival was different for each sex but constant over time received the most support. The estimate of the average annual apparent survival probability obtained with this model was 0.67 for males (95% confidence interval 0.537-0.785) and 0.42 for females (0.290-0.563). Re-encounter probabilities varied between 0.47 and 0.05. The large difference in apparent survival probabilities between males and females found in this study probably reflects a lower site-fidelity of females (i.e. permanent emigration of some birds). The turnover of females observed between the first and second clutches within a single breeding season (Dyrcz & Zdunek 1993a) supports the idea that some females may show quite low site-fidelity at the scale of our study area. Refined analyses of our Aquatic Warbler data will require enlarging the sample size of ringed and recaptured birds to explore annual variation of apparent survival.



► **Fig. 2.7.1**

Aquatic Warbler numbers at the Rietzer See breeding site (Germany) 1969-1974 (Sohns & Wawrzyniak 1973, Wawrzyniak & Sohns 1977, and pers. comm.).

2.7

Box 2.7.2
Survival of Aquatic Warblers breeding in southeastern Poland

JULIEN FOUCHER, JOANNA WOŁOSZKIEWICZ, PAMÉLA LAGRANGE, JANUSZ KLOSKOWSKI & HUBERT DUGUE

Aquatic Warblers were marked with alpha-numeric colour rings from 2013 to 2017 at seven breeding sites in the Lublin region, southeastern Poland: the Tyśmienica river valley, Żelizna Lake, the Bubnów and Staw mires in the Poleski National Park, the Ciesacin mire, Błota Serebryskie, and the Bagno Serebryskie Reserve (Foucher et al. in prep.). The observed return rate was 25% for males and varied from 18 to 34% depending on the year. Females showed a return rate of 13%, ranging from 9 to 17%. The average return rates were not significantly different from those observed between 1986 and 1991 in the Biebrza Marshes in Poland (30 and 9% for males and females, respectively; Dyrcz & Zdunek 1993a). These results are also very similar to the average male return rate of 26%, observed in 2010-2011 in Ukraine (Salewski et al. 2013). Apparent survival probability was estimated in the Mark 8.2 software (White & Burnham 1999). The estimate of adult survival was based on 305 adult individuals, yielding 79 resightings in subsequent years (69 males and 10 females). The model assuming that survival did not vary between the sexes and detection probability was different between the sexes estimated a mean apparent survival of adult Aquatic Warblers of 0.36 ± 0.04 (standard error) and the detection probability was 0.57 ± 0.09 for males and 0.26 ± 0.10 for females.

Population decline in Pomerania

Since Aquatic Warblers abandoned most breeding sites in central and western Poland and Germany during the last decades, the Pomeranian population has become isolated and strongly fragmented. Detailed counts of singing males since 1993 show a steep decline during 1997-2001 (see Chapter 2.2). Little is known of the development before 1993, but numbers may have been even higher in 1991 (Dyrcz & Czeraszkiewicz 1993). The current critically small size of the Pomeranian population, together with the absence of an immediate response to the recent habitat improvement measures, makes it important to understand the reasons for the decline and how to reverse it.

Local increases are possible even in such an overall declining population. On the German side of the Oder Estuary, numbers increased in the 1980s when low intensity grazing was introduced (Sellin 1989b). A similar increase could have occurred on the Polish coastal breeding sites when land use became less intensive due to the crisis of Polish agriculture after 1980. At the same time, since the 1970s inland breeding sites were heavily drained. After 2001, an increase in local numbers occurred in Rozwarowo. Here at least three colour-ringed males from the then declining local population on Karsiborska Kępa were observed in 2006, suggesting emigration of adults over c. 30 km to Rozwarowo – even within one breeding season (G. Kiljan unpubl. data). This confirms that both sites belong to the same, spatially structured population, but it also shows that both factors, local productivity and immigration or emigration, have to be taken into account to understand the causes of local changes in numbers.

Breeding success has not been studied in the Pomeranian population since 1990, although successful breeding was observed in several sites (Tanneberger 2008). Offspring numbers may have been low in these years, either due to a low number of females and, consequently, broods, or due to nest losses. To attribute the 1997-2001 decline solely to differences in breeding success, however, we would have to assume that the average productivity per female dropped by more than 50% for a few years and then increased again thereafter, which seems unlikely. There is thus some reason to assume that a limited breeding output, together with some degree of net emigration, both attributable to insufficient habitat quality, caused the recent decline of this population. Another potential explanation, decreased adult survival for just four years, caused by conditions outside the breeding sites, seems rather unlikely, as similar declines had not been observed at other populations at this time.

The role of non-breeding areas

Since confirmation of the first important wintering site of the species near the delta of the Senegal River in West-Africa, there is now better understanding of the threats to the African wintering sites (see Chapter 2.10). This has led to a growing concern that the decreasing availability of suitable wintering habitat might reduce adult survival and drive the world population into a decline, now or in the near future. In the delta, Aquatic Warblers were only found in the Djoudj National Park region, an island of more or less natural habitat surrounded by areas which have been mostly turned into unfavourable rice fields and freshwater reservoirs (**Box 2.10.1**). It is well documented that fluctuations in numbers of British Sedge Warblers *Acrocephalus schoenobaenus* wintering in the western Sahel region are linked to annual rainfalls. Sedge Warbler numbers showed a marked decline after 1968 when the Sahel drought led to a decrease of winter habitat and consequently of winter survival of the birds (Peach et al. 1991). In contrast, the decline of the Aquatic Warbler was already visible since 1950, when Sahel rainfalls were well above or around the long-term average. There is no evidence that low rainfalls after 1968 caused further declines, and this might be explained by the fact that at that time, the loss of breeding habitat after large -scale drainage in Europe was the main reason for the decline.

Nevertheless, large-scale habitat change, including the building of large-freshwater reservoirs in the areas of previously natural floodplains along the lower Senegal River, and the conversion of floodplain into irrigation agriculture (mostly for rice and sugar cane), has probably reduced the amount of wintering habitat since the early 1960s. Consequently, annual rainfalls ceased to determine the extent of flooded areas and thus suitable winter habitats in the Senegal Delta after 1986 (Zwarts et al. 2009). So far, we can neither confirm nor exclude that the winter habitat is a factor limiting population size, but if habitat destruction continues in Africa, while habitat management and restoration shows effect in Europe, this might become a limiting factor in the future.

2.8 Conservation genetics

VOLKER SALEWSKI & JUSTYNA KUBACKA

The Aquatic Warbler shows an extremely fragmented distribution over its range (see Chapter 2.2). Conservation theory predicts an increased extinction risk for species with few relatively small populations and/or for those living in highly fragmented habitats (Frankham 1996, Purvis et al. 2000). This holds especially for habitat specialists of small body size, such as the Aquatic Warbler (Owens & Bennett 2000). Among the consequences of the isolation of populations is the increased risk of declining genetic diversity, caused by genetic drift, and an increased rate of inbreeding in populations (Croteau et al. 2007). Both can make a species more prone to extinction, because loss of genetic diversity reduces the capacity of the species for adaptation, and inbreeding might compromise the reproductive success of individuals (inbreeding depression), for instance due to a lower hatching rate (Noordwijk & Scharloo 1981, Keller & Waller 2002, Frankham 2005).

The rapid development of genetics and molecular methods during the last few decades, including the increased accessibility to molecular markers, such as microsatellites and, more recently, SNP (single nucleotide polymorphism) data coming from next generation sequencing (NGS) approaches, has opened new horizons for conservation biology (e.g. Frankham 1996, Luikhart et al. 2010, Kraus et al. 2015, Kraus & Wink 2015; see also Chapter 6). The integration of population genetics in conservation research and management is an important tool for the assessment and conservation of the evolutionary potential of species (Laikre 2010). Furthermore, preserving genetic diversity is one of the three conservation goals of the Convention on Biological Diversity, besides preserving the diversity of ecosystems and the diversity of species (CBD 1992).

Among the many questions with respect to population ecology and conservation that can be answered with genetic markers (e.g. Selkoe & Toonen 2006), the following are relevant for Aquatic Warbler conservation:

1) How many subpopulations actually exist? For instance, is the Pomeranian subpopulation genetically distinct from the east-central European subpopulation? Are there unknown breeding subpopulations that may be detected by analysing genetic markers of migrating birds?
2) Have the existing subpopulations expanded or contracted their range in the past?
3) Do subpopulations differ in past and present size?
4) Is there inbreeding depression, with all of its assumed negative effects (Frankham 1996, O'Grady et al. 2006)?
5) From which subpopulation does an individual detected on migration or a wintering sites originate?

Some of these questions were already addressed in two preliminary studies:

- Gießing (2002) used six microsatellite loci to analyse eight main breeding subpopulations (Pomerania, Biebrza, and Chełm Marshes in Poland; Dzikoje, Zvaniec, and JasieÍda in Belarus; Udai and Supii in Ukraine). The gene-tic differentiation between the subpopulations was small, but significant. This suggests that they are indeed separated from each other but some gene flow between them must exist. There were, however, indications that especially the Pomeranian subpopulation is genetically isolated.
- The potential connectivity between the wintering grounds in northern Senegal and the known breeding populations was analysed by Vogel (2009), with the use of the same microsatellite loci as in Gießing (2002). Out of 59 Aquatic Warblers captured in the Djoudj area in northern Senegal, only one could be assigned to a breeding

subpopulation – the Pomeranian population. Using a relaxed criterion for assigning Aquatic Warblers captured in the non-breeding areas to one of the known breeding populations, eight and four birds could be assigned to the Pomeranian and the Lithuanian populations, respectively. However, both Gießing (2002) and Vogel (2009) stressed that more microsatellite loci would be needed for more reliable analyses.

In 2011, the Aquatic Warbler Conservation Team (AWCT) established eleven new microsatellite markers for Aquatic Warblers (Salewski et al. 2012). First results of population genetic analyses performed on samples collected between 1993 and 2012 revealed that the subpopulations investigated (Dzikoje and Zvaniec in Belarus; Tyrai in Lithuania; Biebrza National Park, Chełm Marshes, and Pomerania in Poland; Supii and Udai in Ukraine; and the Hortobágy in Hungary, absent since 2011) show some genetic differentiation, but also that there is sufficient gene flow for them to be not genetically isolated (Salewski et al. in prep.). Another study based on microsatellite markers, carried out in 2014 (i.e. after conservation management in Aquatic Warbler sites had begun, which could affect natal or breeding dispersal), detected no distinct genetic structure across two Polish populations separated by c. 250 km, the Biebrza Valley and the Lublin region (Kubacka et al. in prep).

In the study by Salewski et al. (in prep.), there was no hint of inbreeding in the relatively small and fragmented populations, with the exception of the population in Udai in Ukraine. However, more genetic markers are typically necessary to study inbreeding (e.g. Hoffman et al. 2014). Recently, a project exploring the potential inbreeding depression in the Aquatic Warbler has started in Poland. The project will use SNP markers and a method (RAD-seq) that identifies hundreds or thousands of such markers across the genome, therefore providing a much higher statistical power to detect inbreeding depression than microsatellite markers. This will improve our understanding of the factors limiting the viability of Aquatic Warbler populations (see also Chapter 6).

Although genetic analyses are a strong tool to help identify conservation needs and evaluate management actions, it has to be kept in mind that they are not a means for successful conservation themselves. Knowledge about conservation deficiencies, as revealed by these analyses, must be transformed into appropriate site-specific management activities. Only then will molecular methods serve to aid in the preservation of globally threatened species, such as the Aquatic Warbler.

2.9 Migration

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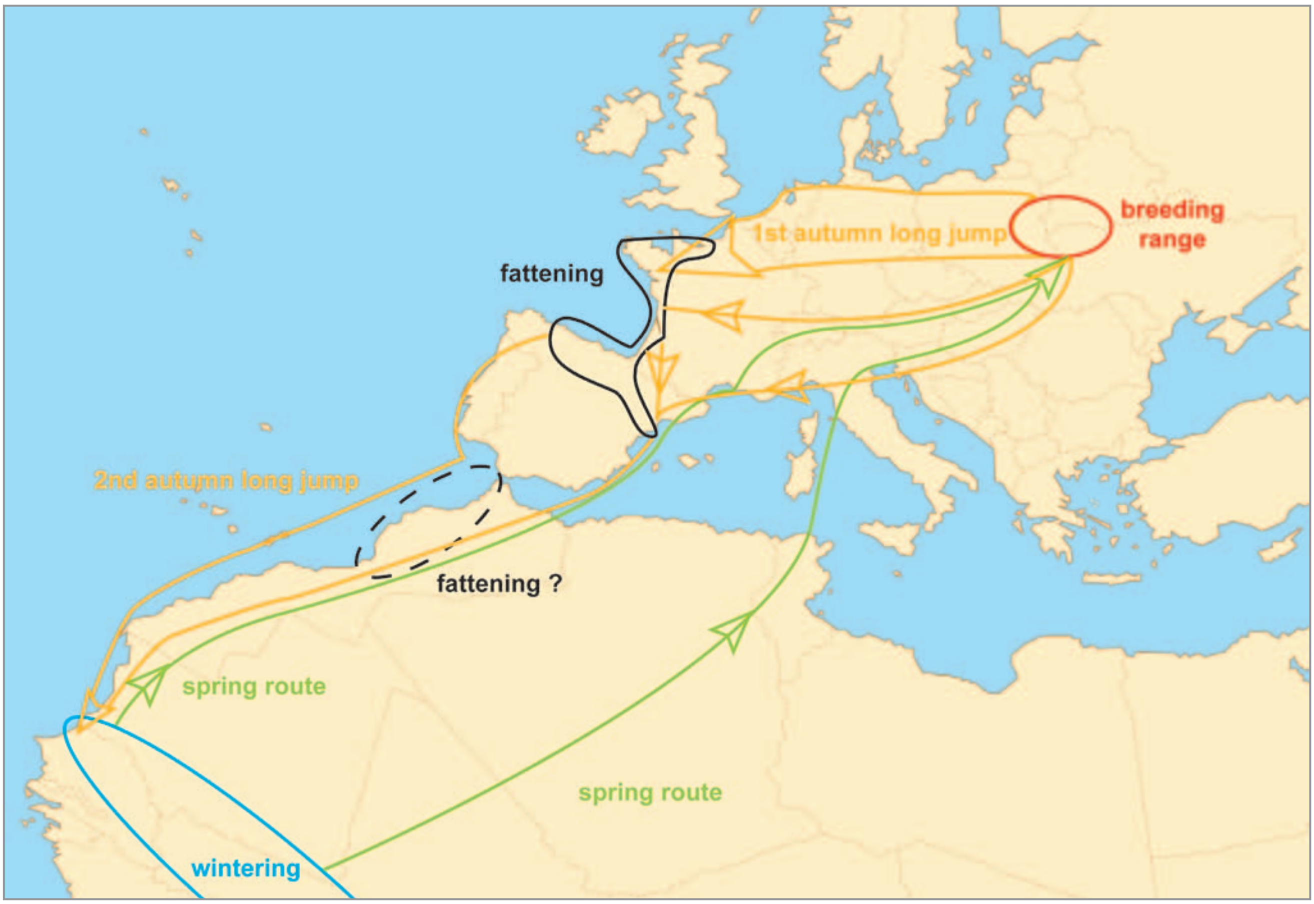
The Aquatic Warbler is a trans-Saharan migrant covering about 6,000 km twice a year (**Fig. 2.9.1**). It is also a very lightweight bird with a high metabolism, as with many migratory insectivore birds, which require fat stocks to fly over long distances. In order for a small bird to perform such a journey, the availability, quality, and distribution of resting and foraging sites are crucial. Evidence suggests that, as many other birds do, Aquatic Warblers have to refuel in particularly favourable areas – stopovers – in order to successfully cross inhospitable regions, where staging areas are rare or non-existent, such as the Bay of Biscay, the Mediterranean Sea, or the Sahara desert. Aquatic Warbler flights are in all likelihood nocturnal, at least in Europe, but diurnal flights could take place during the crossing of extensive ecological barriers.

The migratory behaviour of the Aquatic Warbler has mostly been studied using individual marking (ringing), which is the most reliable method to detect the presence of this species at stopover sites, where it behaves unobtrusively. Ringing programmes and their long-term data, thanks to an extensive network of ringers, especially in western Europe, still remain the best way to understand the migration of the species, including its routes, phenology, fattening, and habitat requirements. In addition, new technologies, such as geolocators, provide unprecedented detailed information on the migration of the Aquatic Warbler and fill some gaps in knowledge. In 2010 and 2012, geolocators were fitted to Aquatic Warblers in order to find their wintering sites as well as their migration timing and route (Salewski et al. 2013, Salewski et al. sub-

▼ **Fig. 2.9.1**
Trajectory of the post-breeding and pre-breeding migration of Aquatic Warblers showing the locations where most fattening occurs (in black). The breeding range depicts the area where the majority of Aquatic Warblers breed (map by A. Le Nevé)**.**



mitted; see **Box 2.9.1** and Chapter 2.10).

Throughout the chapter, we did not use the Acrola index, which is the total number of Aquatic Warblers divided by the total number of *Acrocephalus* warblers captured (Julliard et al. 2006), and corrects the number of Aquatic Warblers caught on migration for site-specific confounding variables, such as the use of playback, duration of mist-netting, length of mist-nets, duration of ringing effort, or habitat type. Comparison between countries was not the aim of this chapter and we lacked detailed data for all of the countries. Therefore, the numbers of Aquatic Warblers captured on migration provided below are not comparable between stopover countries.

▼ **Table 2.9.1**
Summary of recoveries of Aquatic Warblers ringed on their breeding grounds, or just after the onset of migration (Siemianówka and Rakutowskie lakes), and retrapped in the same or later year during their post-nuptial migration. Each row represents a unique bird (source: CRBPO, the authors, and J. Kubacka pers. comm.).

Location of ringing	Location of recovery	Ringing date	Recovery date	Age at ringing	Sex	Latitude of recovery
Belarus, Dzikoje Mire	France, Loire Estuary	2004-06-13	2004-09-01	AD		47
Belarus, Dzikoje Mire	France, RNN de la Mazière	2002-06-10	2002-08-17	AD		44
Belarus, Sporava Mire	Spain, Laguna de la Nava	2006-06-18	2009-08-11	AD	M	42
Belarus, Zvaniec Mire	Spain, Laguna de la Nava	2003-07-24	2003-09-22	JUV		42
Lithuania, Nemunas Delta	Belgium, Watervliet	2017-05-21	2017-08-01	AD		51
Lithuania, Nemunas Delta	France, Seine Estuary	2015-08-02	2015-08-12	AD	M	49
Lithuania, Nemunas Delta	France, Loire Estuary	2016-07-30	2016-08-23	JUV		47
Lithuania, Nemunas Delta	Spain, Atapuerca, Lagunas de Atapuerca	2015-08-02	2015-08-30	AD	M	42
Lithuania, Nemunas Delta	Portugal, Salreu	2017-07-07	2017-08-17	AD	M	40
Poland, Biebrza Marshes, Ławki Mire	Belgium, Veurne	1989-06-19	1990-08-13	AD	M	51
Poland, Biebrza Marshes, Ławki Mire	Belgium, Veurne	2005-05-26	2005-08-05	AD		51
Poland, Biebrza Marshes, Ławki Mire	Belgium, Antwerpen, Oorderen	2010-06-05	2010-08-02	JUV		51
Poland, Biebrza Marshes, Ławki Mire	France, Tréogat, Trunvel	1990-06-05	1990-08-04	JUV		47
Poland, Biebrza Marshes, Ławki Mire	France, Tréogat, Trunvel	1990-06-14	1990-08-14	JUV		47
Poland, Biebrza Marshes, Ławki Mire	France, Tréogat, Trunvel	1993-06-??	1993-08-18	JUV		47
Poland, Biebrza Marshes, Ławki Mire	France, Tréogat, Trunvel	1995-06-15	1995-08-19	JUV		47
Poland, Biebrza Marshes, Ławki Mire	France, Loire Estuary	2005-07-09	2005-08-15	JUV		47
Poland, Biebrza Marshes, Ławki Mire	France, Loire Estuary	09.07.2014	27.08.2014	JUV		47
Poland, Chełm Marshes	Belgium, Antwerpen, Oorderen	2014-06-18	2014-08-24	JUV		51
Poland, Chełm Marshes	Belgium, Veurne	2015-06-23	2015-08-07	JUV		51
Poland, Chełm Marshes	Spain, Laguna de la Nava	1998-06-22	2000-08-05	AD		42
Poland, Chełm Marshes	France, Canet-en-Roussillon	17.06.2014	20.04.2015	AD	M	42
Poland, Ciesacin Reserve	Spain, Ría de Villaviciosa, Porreo de Villaverde	2015-07-11	2015-08-23	AD	F	43
Poland, Poleski National Park	Portugal, Salreu	2015-07-24	2015-08-21	AD	F	40
Poland, Pomerania, Karsiborska Kępa	Spain, Laguna de la Nava	1999-06-10	2000-08-01	JUV		42
Poland, Rakutowskie Lake	France, Loire Estuary	2013-07-31	2013-08-10	JUV		47
Poland, Siemianówka Lake	Belgium, Veurne	2006-07-21	2006-08-11	JUV		51
Ukraine, Upper Prypiat	Netherlands, Zandvoort	2001-07-25	2001-08-20	?		52

Location of ringing	Location of recovery	Ringing date	Recovery date	Age at ringing	Sex	Latitude of ringing
France, Merlimont, Marais de Balançon	Belarus, Dzikoje Mire	2011-07-31	2012-06-25	JUV	M	50
France, Sélune Estuary	Belarus, Dzikoje Mire	2011-08-16	2012-06-25	JUV	M	48
France, Seine Estuary	Belarus, Zvaniec Mire	2013-08-09	2016-06-11	JUV	F	49
France, Seine Estuary	Belarus, Zvaniec Mire	2016-08-27	2017-07-17	JUV	F	49
France, Baie de l'Aiguillon	Belarus, Zvaniec Mire	2012-08-16	2014-07-24	JUV	F	46
Spain, Arguedas, El Raso	Hungary, Hortobágy National Park	2008-08-09	2010-06-25	JUV		42
France, Seine Estuary	Lithuania, Nemunas Delta	2015-08-12	2016-07-06	JUV	M	49
France, Seine Estuary	Lithuania, Nemunas Delta	2016-08-16	2017-06-22	JUV	M	49
France, Loire Estuary	Lithuania, Nemunas Delta	2016-08-30	2017-06-27	JUV	F	47
France, Loire Estuary	Lithuania, Nemunas Delta	2013-08-20	2015-07-03	JUV	M	47
France, Loire Estuary	Lithuania, Nemunas Delta	2016-09-03	2017-05-21	JUV	M	47
France, Loire Estuary	Lithuania, Nemunas Delta	2013-08-08	2015-06-05	JUV	M	47
France, RNN de Moëze-Oléron	Lithuania, Nemunas Delta	2016-09-08	2017-07-22	JUV	M	45
France, RNN de la Mazière	Lithuania, Nemunas Delta	2011-08-19	2015-06-10	JUV	M	44
Spain, Laguna Grajalejo de Las Matas	Lithuania, Nemunas Delta	2012-08-14	2014-07-06	JUV		42
Netherlands, Friesland, Vlieland	Poland, Biebrza Marshes	2010-08-08	2014-07-25	JUV		53
Belgium, Zeebrugge	Poland, Biebrza Marshes, Ławki Mire	1989-08-14	1990-08-17	AD	M	51
France, Loire Estuary	Poland, Biebrza Marshes, Ławki Mire	2016-09-02	2017-05-15	JUV	M	47
France, Loire Estuary	Poland, Biebrza Marshes, Ławki Mire	2013-08-12	2014-07-07	JUV	M	47
France, Tréogat, Trunvel	Poland, Biebrza Marshes, Ławki Mire	2016-08-13	2017-07-03	JUV	F	47
France, Baie de l'Aiguillon	Poland, Biebrza Marshes, Ławki Mire	09.08.2014	15.05.2017	AD	M	46
France, Gironde Estuary	Poland, Biebrza Marshes, Ławki Mire	31.08.2014	06.06.2017	JUV	F	45
France, Saint-Philbert-de-Grandlieu	Poland, Biebrza Marshes, Mścichy	2011-08-27	2013-07-07	JUV	M	47
Portugal, Salreu	Poland, Biebrza Marshes, Mścichy	2015-09-04	2017-07-23	AD	F	40
France, Loire Estuary	Poland, Chełm Marshes	2013-08-22	2014-06-14	AD	F	47
France, Soulaire-et-Bourg (Loire Estuary)	Poland, Chełm Marshes	07.08.2013	14.06.2014	AD	M	47
France, Soulaire-et-Bourg (Loire Estuary)	Poland, Chełm Marshes	07.08.2013	15.07.2016	AD	M	47
France, Gironde Estuary	Poland, Chełm Marshes	2013-08-28	2014-06-14	JUV	M	45
Spain, Laguna de la Nava	Poland, Chełm Marshes	2012-08-29	2013-06-30	JUV		42
Spain, Laguna de Villagán	Poland, Chełm Marshes	2011-08-24	2013-07-01	JUV		42
Spain, Laguna de Villagán	Poland, Chełm Marshes	2011-08-24	2014-06-09	JUV		42
France, La Neuville, Bassins des Cinq Tailles	Poland, Ciesacin Mire	2012-08-27	2013-07-05	JUV	M	50
France, La Neuville, Bassins des Cinq Tailles	Poland, Ciesacin Mire	2012-08-27	2015-07-11	JUV	M	50
Belgium, Veurne	Poland, Odra Valley, Krajnik	2000-08-12	2002-07-20	AD	F	51
Belgium, Veurne	Poland, Poleski National Park	2012-08-11	2015-07-20	AD	M	51
Belgium, Veurne	Poland, Poleski National Park	2012-08-11	2016-07-08	AD	M	51
Belgium, Veurne	Poland, Poleski National Park	2012-08-11	2017-06-02	AD	M	51
France, Baie de Somme	Poland, Tyśmienica Valley	2014-08-19	2015-07-21	JUV	M	50
France, Loire Estuary	Ukraine, Supii, Vilne-Berezanka	2009-08-14	2010-07-06	JUV		47
France, Gironde Estuary	Ukraine, Supii, Vilne-Berezanka	2012-08-14	2013-05-30	JUV	M	45
France, Villefranque, Barthes de Quartier Bas	Ukraine, Supii, Vilne-Berezanka	2011-08-18	2012-07-04	JUV	M	43
France, Villefranque, Barthes de Quartier Bas	Ukraine, Supii, Vilne-Berezanka	2011-08-18	2013-05-27	JUV	M	43
France, Villefranque, Barthes de Quartier Bas	Ukraine, Supii, Vilne-Berezanka	2011-08-18	2012-07-04	JUV	M	43
France, Villefranque, Barthes de Quartier Bas	Ukraine, Supii, Vilne-Berezanka	2011-08-18	2013-05-27	JUV	M	43

Connectivity

On their breeding grounds, Aquatic Warblers have been ringed mostly in Poland, Belarus, and Lithuania (see **Table 2.9.1**). The ringing effort on breeding grounds relies only on research projects and the number of ringed birds varies accordingly. Birds ringed in Poland (in both the West and East of the country), Belarus, Lithuania, and Ukraine have been recaptured in the Netherlands, Belgium, the UK, France, Spain and Portugal (N. Roothaert unpubl. data, L. Roothaert, A. Dyrcz, O. Dehorter, and CRBPO pers. comm.), suggesting autumn migration along the Atlantic coast. Birds with rings from these stopover countries have been recaptured in central and eastern Poland, Lithuania, Hungary, Belarus, as well as in the easternmost breeding site in Ukraine, Supii (see **Table 2.9.2**). Several birds ringed in France and Spain on post-nuptial migration were recovered in January and February in Djoudj, Senegal (see also Chapter 2.10).

The geolocator data showing that the studied adult males from central Ukraine (Supii) and Belarus (Dzikoje) migrate to Mali, together with two ring recoveries (Inner Niger Delta in Mali – central Ukraine; Djoudj in Senegal – Biebrza Valley; Poluda et al. 2012; see also **Box 2.9.1** and **Fig. 2.10.14**) point to the hypothesis that the northwesternmost Aquatic Warbler populations from the Biebrza Valley (and possibly also Lithuania) rather migrate on a westerly route to Senegal, whereas the Belarusian and Ukrainian populations migrate further east to spend the winter in Mali and adjacent areas. This hypothesis is still to be tested for the northwestern populations (as it is planned with a new geolocator project in 2018/2019, M. Flade pers. comm.). The probable wintering of Pomeranian and Lithuanian breeding populations in the Senegal Delta is also supported by the genetic analysis of wintering birds in Djoudj (see Chapter 2.8).

◄ **Table 2.9.2**
Summary of recoveries of Aquatic Warblers ringed on migration stopovers and retrapped in later years on their breeding grounds (source: CRBPO, the authors, and J. Kubacka pers. comm.).

Box 2.9.1
Geolocator research

VOLKER SALEWSKI & MARTIN FLADE

With a mass of c. 12 g, the Aquatic Warbler cannot carry a satellite tag to accurately track its migration routes. Recently, migration flyways of the species were studied using geolocators, durable and lightweight (0.6 g) devices. The Aquatic Warbler is, to date, one of the smallest birds ever fitted with this kind of device, thanks to new lightweight models (Salewski & Poluda 2010). These geolocators record the timing of sunrise and sunset and, by comparing the day length and the time of sunrise and sunset to the standard time at the null meridian, and by assessing the sunrise angle, it is possible to infer the latitude and longitude of the geolocator's position for each day. In order to limit the weight of the device, it does not have the ability to transmit data; hence, the birds equipped with geolocators must be recaptured for data retrieval. Disadvantages, therefore, include low recovery rates due to low return rates of the birds and relatively high error rates. Still, with algorithms to translate the sunlight measurements constantly improving, geolocators make a helpful tool to study migration and wintering.

In June 2010, geolocators where fitted to 30 male Aquatic Warblers in the Supii Marshes in Ukraine. Six geolocators were recovered in 2011 and three devices with complete data were retrieved. The results indicated a formerly unknown post-nuptial migration route to African wintering sites, with the birds crossing southern Europe south of the Alps to reach stopover sites in southwestern France and Spain (Salewski et al. 2013). The data were later reanalysed with a new method, yielding the same results (Salewski et al. submitted).

To verify the new southern route, additional 46 males in Dzikoje in western Belarus and in the Supii Marshes in central Ukraine were fitted with geolocators in 2012. All the individuals carrying a geolocator left the breeding grounds between 9 and 24 July. After initially travelling in a southwestern (three birds) or southern direction, all the birds seem to have moved west through southcentral or southern Europe towards the Iberian Peninsula and Southwest-France, where they arrived already between 24 July and 7 August. One bird may have migrated from northern Italy directly to North-Africa, possibly via the Balearic Islands. One individual from Dzikoje had two clear but short stopovers in southeastern Europe (Bulgaria, Greece) from where it flew via Italy towards the Iberian Peninsula. Two individuals interrupted their migration for a few days in northern Italy, whereas one bird migrated directly from its breeding site in Dzikoje to northern Spain (Salewski et al. submitted). This research also stresses the importance of wetlands on the Iberian Peninsula and in Morocco for Aquatic Warbler migration, and the need to preserve them along the stopover sites in France.

It has to be taken into consideration that migration routes vary by the age and possibly also the sex of individuals (e.g. Miguélez et al. 2014), and since all the birds fitted with geolocators were adult males, the described migration route south of the Alps might be only taken by adults, or even only by adult males.

2.9

Post-nuptial migration routes

Juveniles (and some adults) mainly travel along the western route through Poland and Germany, and then along the West-European coastline from the Netherlands (van Eerde 1998) to Belgium and France (de By 1990, in Julliard et al. 2006), whereas at least adult males from western Belarus and central Ukraine travel towards the Balkan peninsula and then fly south-west, crossing the Mediterranean basin south of the Alps to their first stopover sites in France and the Iberian peninsula (Salewski et al. 2013, Salewski et al. submitted; see **Box 2.9.1**). Subsequently, Aquatic Warblers follow the English Channel and the Atlantic coast of France. England, where a dozen individuals are captured each year (St-Pierre & Lock 2008), is little frequented.

In Belgium, 2,180 Aquatic Warblers were ringed between 1964 and 2017 (Belgian Ringing Scheme, RBINS). The main ringing site is an estate of decantation basins at Veurne, 6 km from the coastline (N=910, N. Roothaert unpubl. data). However, it is necessary to clarify that ringing stations in Belgium use tape lure all the night to broadcast the song of the Aquatic Warbler, which could then artificially stop migrating birds on these stations.

France is one of the European countries hosting the highest number of Aquatic Warblers during post-breeding migration (between 24,000 and 30,000 individuals were ringed as of 2011), suggesting that probably all first-year Aquatic Warblers migrate by this western flyway and stop in France to refuel (Jiguet et al. 2011). In this country, birds are mainly detected from the North along the English Channel and the Atlantic coastline, through the department of Loire-Atlantique (the second most important region after Camargue in terms of wetland area in France), including the Brière Marshes (20,000 ha), the Loire Estuary (10,000 ha) and Grandlieu's Lake (Foucher et al. 2014), down to the Gironde Estuary (which holds important area of salt marshes – about 1,500 ha – and is an important stopover site for the Aquatic Warbler; see Musseau & Hermann 2013 and Musseau et al. 2014), and the Pyrenean Atlantic border. However, it must be considered that almost no search of the species has been carried out in continental France (as opposed to coastal France), to investigate possible inland diffuse migration. This may represent an important bias for our understanding of Aquatic Warbler migration over the land (as suggested by some recoveries, for example the recapture of a juvenile ringed at Arraincourt, Northeast-France, on 4 August 2010, and its further recapture five days later at Donges in the Loire Estuary – western France). Indeed, some birds fly north-west of the Alps via Switzerland, where 55% of recoveries (N=101 between 1980 and 2003) occurred during the autumn migration (Maumary et al. 2007).

The birds then cross the whole width of the Iberian Peninsula, having been detected in the East, from the Ebro Delta along the Mediterranean coastline, inland, and especially in the West, where they seem far more abundant (Atienza et al. 2001, Jubete 2001, Robles & Arcas 2004, Miguelez et al. 2009, Neto et al. 2010). Laguna de la Nava in the Palencia region (northern Spain) is the main identified site (840 birds ringed from 1999 to 2017).

Subsequently they reach the Moroccan coast (H. Rguibi Idrissi unpubl. data) and go on to sub-Saharan West-Africa (Schäffer et al. 2006). The wetlands of the Moroccan coastline, such as Larache and the Sidi Boughaba Marshes, the Merja-Zerga Lagoon, the Bay of Azemmour-El Jadida, the Lagoon of Oualidia, and the Wadi Massa (Rguibi Idrissi 2002, Rguibi Idrissi et al. 2007), might also be preferred as fattening areas before flying across the Sahara, according to recent autumn records from Morocco (R. Idrissi unpubl. data). However, despite expeditions to Morocco in mid-September 2009 (P. Provost pers. comm.), in August 2012 (Le Nevé et al. 2013a), in November 2013 (J. Foucher unpubl. data), and in September 2015 (R. Musseau and R. Idrissi unpubl. data), Aquatic Warblers were not found, and the use of stopover migration sites in this country remains largely unknown.

	Juveniles				Adults			
	N	Average mass (g)	Minimum mass (g)	Maximum mass (g)	N	Average mass (g)	Minimum mass (g)	Maximum mass (g)
2008	353	11.38	9.0	16.6	57	11.89	10.2	17.9
2009	764	11.12	8.8	17.0	113	11.39	9.3	14.2
2010	474	11.21	9.2	17.7	101	11.53	9.6	15.1
2011	964	11.12	8.5	19.2	227	11.55	9.5	15.7
Total	2,555	11.17			498	11.55		

◄ **Table 2.9.3**
Weight of adult and juvenile Aquatic Warblers captured in France between 2008 and 2011 during post-nuptial migration (data from CRBPO Bird-Ringing Research Centre and Le Nevé et al. 2013b).

Not much ringing is carried out at favourable sites on the French Mediterranean coastline in August-September, but the few attempts that have been made, in addition to observations, highlighted the rarity of the species on these grounds (0.43% of the national data, eleven captures and 23 observations from 1980 to 2012; N=7,996). Hence, ringing data seem to exclude the existence of massive migration following this route. However, it is supported by geolocator results (see above).

Scattered older records from Bulgaria, Cyprus, Turkey, Egypt, and Jordan (Schäffer et al. 2006) suggest the possibility that at least some decades ago a much less frequented flyway existed along the Black and the Mediterranean Seas, which was possibly connected with Russian and West-Siberian breeding populations (now extinct).

In eastern Greece, it seems that migratory Aquatic Warblers are absent or extremely rare. None were seen or caught during ringing campaigns organised in the Evros Delta (40.49 N, 25.29 E) in a suitable habitat during both pre- and post-nuptial migration between 1997-2008 (April-May, September) when a grand total of 21,730 Sedge Warblers *Acrocephalus schoenobaenus* and Reed Warblers *A. scirpaceus* were ringed (D. Vangeluwe pers. comm.).

Post-nuptial migration refuelling strategy

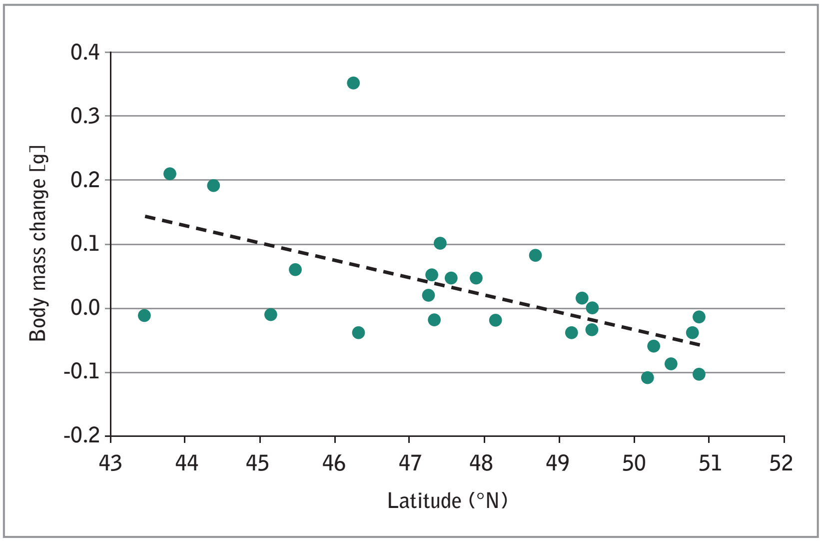
It is possible that Aquatic Warblers leave the breeding areas with just enough fat to reach the North Sea and the English Channel coastline.

In the Netherlands, the birds do not make long stopovers at the sites where they are ringed: out of 613 birds caught between 1943 and 2013, only three individuals were re-trapped at the same site (van der Spek et al. 2017).

In Belgium, the main place where Aquatic Warblers have been ringed during the post-nuptial migration so far (N=1,584; RBINS) is the coastal site of Veurne. The weight range of the birds caught there lies between 9.1 g and 14.8 g. The mean fat score according to Busse (1974), measured on the scale between 0 and 5 for fat deposits in the furcular depression, was 1.46 (N=893, N. Roothaert unpubl. data). In France, between 2008 and 2011, the lightest bird weighed 8.8 g, whereas the heaviest one weighed 19.2 g (**Table 2.9.3**).

In France, coastline marshes located from the North down to the Southwest (Julliard et al. 2006, Le Nevé et al. 2011, Le Nevé et al. 2013b) provide adequate conditions for fattening. French ringing sites highlighted a latitudinal gradient from the North to the South, showing that fattening begins roughly south of latitude 49° N (**Fig. 2.9.2**). In the coastal marshes of the Gironde Estuary, birds accumulated on average 1.46 ±0.59% of their initial mass per day, with a significant difference between fat and lean birds. Individuals with an initial body mass index (ratio of the body mass measured at first capture and wing length) greater than the median, 0.17 accumulated 0.12 ±0.56% of their initial body mass per

2.9



▲ **Fig. 2.9.2** **Relationship between relative mass change per site and latitude from 2008 to 2011 in France (N=26 ringing stations and 125 same-site recoveries). The linear regression ($p=0.002$, $R^2=0.35$) indicates that fattening is positive below latitude 49° N** (Latraube & Le Nevé 2014).

day, whereas lean birds (mass index ⩽0.17) increased by 2.81 ±0.89% of their initial body mass per day (Musseau et al. 2014). At the stopover site of East-Donges in the Loire Estuary, the average fattening rate was 0.26 ±0.15 g per day (Foucher et al. 2014), which corresponds to an increase of 2.33 ±1.34%, assuming an average body mass of 11.2 g. A study carried out at Donges showed that for individuals with the highest relative fuel load the potential non-stop flight distance was (mean ±SD) 926 ±282 km for immatures and 1,178 ±149 km for adults, which indicates that Aquatic Warblers do not fly directly to their wintering grounds after fattening but refuel repeatedly at a few stopover sites in western Europe and the southern Mediterranean (Jakubas et al. 2014).

In Spain, the coastline marshes in the Northwest (Cantabria and Atlantic coast) and the lagoons of inland northwestern Spain seem to offer suitable conditions for fattening.

Heavy weights were also recorded in Portugal, where the maximum was 17.6 g, with recent local recaptures indicating that the Iberian Peninsula is also used for fattening during the autumn migration (Neto et al. 2010, J. M. Neto unpubl. data).

Post-nuptial speed of migration

The speed of migration is closely linked to the refuelling strategy, and for each bird it depends on its needs for feeding, fattening, and resting.

The average speed is calculated based on the difference between the date of the last capture at site A and the date of the first capture at site B, and the distance between them. The method is not precise, because the last capture at site A does not necessarily correspond to the last date on which birds exploit the site, and the first capture at site B does not necessarily correspond to the first date on which birds exploit this new site. According to the capture-recapture data analysis by Musseau et al. (2014), the stopover duration is 6.46 ±0.46 days (95% CI: 4.44-9.61) in the Gironde Estuary, with similar values of 6-7 days, depending on the year, in the Loire Estuary (Foucher et al. 2010, Chenaval et al. 2011), which means that there could be up to about 10 days of uncertainty when average speed is calculated.

From the Netherlands to Spain and Portugal, the birds would migrate at a median speed of 55 km a day and an average speed of 68 km a day (N=131 travels by juveniles, 6 by adults and one by a bird of an unknown age, from 1989 to 2017), as they spend a long time at favoured stopovers in order to fatten up (Le Nevé et al. 2013b).

Pre-nuptial migration routes

The pre-nuptial migration has to be considered as a loop migration at least for part of the juveniles, as it seems to favour a more easterly straight route that could match the autumn route of adult males (**Box 2.9.1**).

Two routes appear to be preferred (**Fig. 2.9.1**): an eastern route through central Sahara and towards central Mediterranean, and a western route, probably mainly used by the Aquatic Warblers from the western part of the breeding range (Germany, Poland, and Lithuania), through western Sahara and the Mediterranean coastline of Spain (Atienza et al. 2001) and France to the Rhône Valley (Zucca & le CMR 2004, 2005, 2007, Zucca et al. 2008, 2009, Poulin 2010), then Switzerland (Maumary et al. 2007) and Austria (where a ringed bird was killed by a cat on 26 April 2012, first captured as a juvenile in the Loire Estuary on 18 August 2011).

The route towards the centre of the Mediterranean basin, and then via Italy and the northern Balkan towards central Europe, with at least some birds having a longer stopover in southeastern central Europe (Slovakia, Hungary) is supported by geolocator results (Salewski et al. 2013), as well as observations and ring recoveries in the Czech Republic (Flousek & Cepák 2013) and Slovakia (Trnka et al. 2008). It is also in line with observations in Italy (such as the recovery of a ringed bird at Capraia Island on 17 April 1996), Corsica, and the South of Tunisia, including birds found dead in the garden of a mosque in northern Mali (Schäffer et al. 2006), and an observation of a singing male on 27 May 2008 at Al Marj (Cyrenaica) in Libya (J. Hering via M. Flade pers. comm.).

The Spanish and French Mediterranean coastal route is also supported by recent captures and observations. From 19 to 28 April 2012, an expedition caught 32 birds with low mist nets in suitable habitats at two lagoons on the western part of the Mediterranean coast of France (Le Nevé et al. 2013c). This discovery has now been followed each year on the western Mediterranean coast of France by around ten sightings between mid-April to early May (League for the Protection of Birds 2017).

In Switzerland, 46% of the 556 observations of the species between 1960 and 2003 occurred in spring (Maumary et al. 2007), on a migration route that skirts the Alpine Arc. These observations were mostly made before 1980 and referred most likely to the former East-German and Pomeranian population, which is nearly extinct now. Vallotton & Piot (2010) describe a stable sighting average of 2.4 birds per year in the period 1992-2009 against ten birds per year during the 1960s, despite an increased birdwatching effort. Likewise, the only spring contact in Belgium was one bird ringed in Maaseik (in the East of the country) on 26 April 1964 (RBINS). However, some birds are still observed in spring in the East of France (Rhône Valley, Jura mountains, Alsace and Lorraine; eleven observations between 2001 and 2017; League for the Protection of Birds 2017).

In spring, Aquatic Warblers have never been detected in the western part of Portugal, where the ringing effort has been very low, but three observations are known from the Atlantic coast of France: one in the spring of 1994 and two in 2012 (Orx marshes, Gironde Estuary with photos, and Loire Estuary; S. Tillo pers. comm, H. Dugué unpubl. data). Moreover, some birds have been ringed in spring in the West of Spain (Laguna de la Nava; six birds between 2004 and 2007).

Table 2.9.4

Fastest speeds recorded for the Aquatic Warbler during autumn migration.

Ringing site	Recapture site	Date of ringing	Date of recapture	Distance (km)	Time (No. of days)	Speed (km/day)	Age
UK, Weymouth	France, Oudalle (Seine Estuary)	2006-08-18	2006-08-19	235	1	235	?
France, Chenac-St-Seurin-d'Uzet (Gironde Estuary)	France, Villefranque	2010-08-26	2010-08-27	232	1	232	JUV
France, Mortagne sur-Gironde (Gironde Estuary)	France, Donges (Loire Estuary)	2012-08-26	2012-08-27	227	1	227	JUV
Belgium, Zwevegem	France, Plomodiern	2012-08-08	2012-08-11	625	3	208	JUV

Crossing of seas and deserts

The Aquatic Warbler is expected to avoid long trips over the sea, although the available data are scarce. Some indication is given by the speed of migration. Studies have reported a flight speed of 35 km/h for a little passerine (Backman & Alerstam 2003) and a study of the habitat selection by the Aquatic Warbler at Trunvel, France, in 2001 and 2002 revealed that birds fitted with radio-transmitters did not leave the site before midnight (N=1 adult and 21 juveniles), which limits the nocturnal fly time to 6 hours maximum in August (A. Le Nevé unpubl. data). With these conditions, a bird should fly 210 km per night. This figure matches the data from the recoveries of ringed Aquatic Warblers during autumn migration (N=172 travels), which show that the fastest speed recorded reached 235 km per day, and the four fastest speeds exceeded 200 km per day (**Table 2.9.4**). In addition, one of those four travels is a retro-migration and another individual travelled for three days at an average speed of 208 km per day.

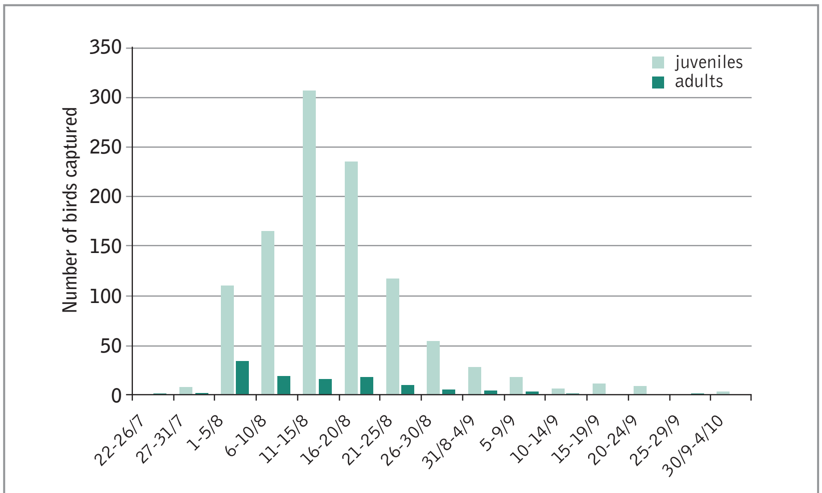
Thus, none of the two more westerly ringed birds in France, at the Trunvel site, recaptured in northwestern Spain (Laguna de la Nava; distance of 650 km) and Portugal (Salreu; distance of 864 km) in 2003 and 2017, respectively, during the post-nuptial migration, enabled us to assert that Aquatic Warblers cross the Bay of Biscay, because their travel duration, six and ten days, respectively, is enough for them to skirt the bay by following the coastline. In pre-nuptial migration, the Aquatic Warbler flies back north by-passing the Mediterranean Sea along the eastern coast of Spain (Atienza et al. 2001) or by crossing it at its narrowest point, between Tunisia and Italy. These stretches of sea could be the widest that it would have to cross (200 km at the most).

It is unknown how many and which Aquatic Warblers cross the Sahara along the coastline, and which ones cross the desert over land. The ring of an individual captured on 24 August 1990 at the farthest point of Brittany in France (Trunvel ringing station), found on 15 September in the pellet of an Eleonora's Falcon on Lanzarote at the Canary Islands supports the coastal hypothesis. Furthermore, most of the bird records are located along the coastline (Schäffer et al. 2006), but this could result from bias in observation effort and does not exclude an overland crossing of the Sahara. On the other hand, the most recent geolocator study indicated that all the adult males from Ukraine and Belarus equipped with geolocators took the inland route (Salewski et al. submitted; see also **Box 2.9.1**).

Effect of age and sex on migration strategies and routes

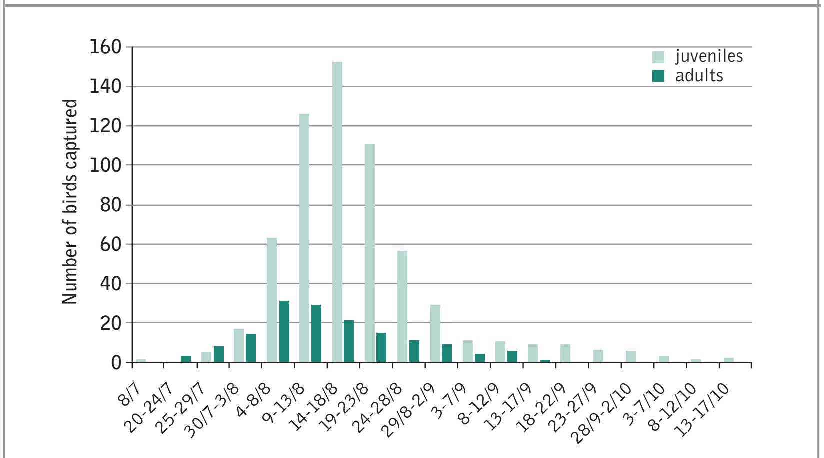
Aquatic Warbler migration routes were observed to vary according to age class. It is also possible that the routes are similar, but the age classes may spend different times at different stopovers, which affects their probability of capture and perceived age and sex ratios. At the Makkumer Zuidwaard site in Holland, a total of 71 birds were caught during the period 1986-1996, of which only one was an adult (van Eerde 1998), whereas van der Spek et al. (2017) indicate an adult proportion of 4.9% for the 448 birds ringed and aged from 1989 to 2014. At the two main ringing sites in Belgium – Veurne and Zeebrugge – adults represented 12% of the total number of ringed birds (N=1,182; N. Roothaert pers. comm.; **Fig. 2.9.3**). In France (**Fig. 2.9.4**), adults represented 13.5% of the captures (N=1,325) in 2008 and 2009 (Le Nevé et al. 2011), 18% in 2010 and 2011 (N=1,884; Le Nevé et al. 2013b) and from 23.6 to 25.1% between 2013 and 2016 (Hemery et al. 2017). Also in France, an age ratio analysis revealed a latitudinal gradient with an increasing percentage of adults further south (**Table 2.9.5**). In Spain, of a total of 576 individuals captured at Laguna de la Nava from 2000 to 2005, 242 (42%) were adults (Jubete et al. 2006) (**Fig. 2.9.5**), and in Portugal, the proportion of adults was 49% for 69 captures between 1977 and 2008 (Neto et al. 2010). This indicates that the adults have a different migration strategy from the juveniles, with longer flights and different stopover sites. Age-specific migratory behaviour was also suggested by Miguélez et al. (2014), who used long-term ringing data to show that the proportion of young Aquatic Warblers migrating over the Iberian Peninsula decreased westwards.

There may also be a difference in migration pattern (timing, duration of stopovers and migration routes) between males and females. At the sites of Veurne and Zeebrugge in Belgium, 73 adult birds were sexed using cloacal protuberance or brood patch, and 80% of all males were recorded before 15 August (although cloacal protuberance is still pronounced after this date), whereas the migration of females continued until 9 September (N. Roothaert unpubl. data). Unfortunately, the more the migration period advances, the less those characteristics for sexing are useful. A study in which Aquatic Warblers caught in the Loire Estuary were sexed using molecular methods found that, while the timing of migration was similar between the sexes in first-year birds, the median date of passage of adult males was eight days earlier than that of females, and nine days earlier than that of immature males (Wojczulanis-Jakubas et al. 2013; **Fig. 2.9.6**). A recent study, based on a range of stopover sites in France and the Iberian Peninsula, in which birds were sexed genetically, revealed that during the autumn migration the proportion of males is higher in western France than in Spain and Portugal. This suggests that the sexes may use these stopover sites differently, with males spending more time in France and females being relatively more abundant in the Iberian Peninsula, though other explanations are possible (Wojczulanis-Jakubas et al. 2017; **Fig. 2.9.7**).



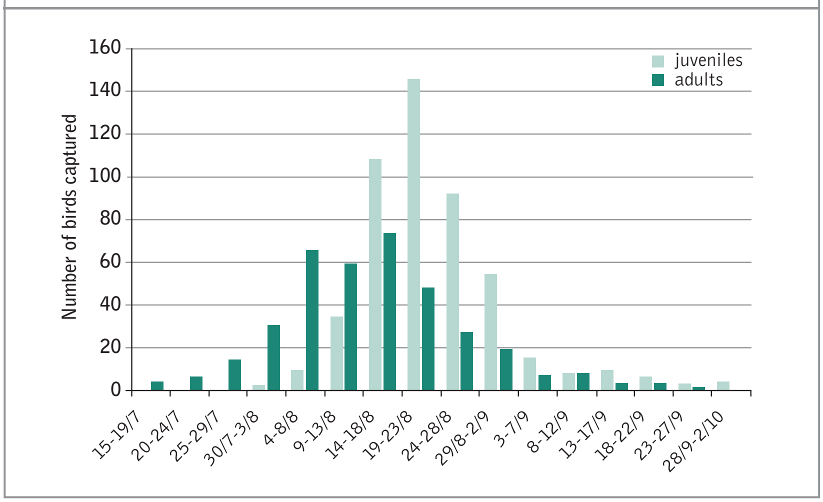
► **Fig. 2.9.3**

Phenology of Aquatic Warbler autumn migration at two main ringing sites (Veurne and Zeebrugge) in Belgium in 1987-2017 (N=1,068 juveniles and 114 adults; N. Roothaert pers. comm.). Mean number of individuals captured per a five-day period is shown.



► **Fig. 2.9.4**

Phenology of Aquatic Warbler autumn migration in France between 2008 and 2016 (N=5,155 juveniles and 982 adults; Le Nevé et al. 2013b and A. Le Nevé pers. comm.). Mean number of individuals captured per a five-day period (weighted by daily means) is shown.



► **Fig. 2.9.5**

Phenology of Aquatic Warbler autumn migration in Laguna de la Nava, Spain between 1999-2017 (C. Zumalacárregui Martínez unpubl. data). Mean number of individuals captured per a five-day period is shown.

2.9

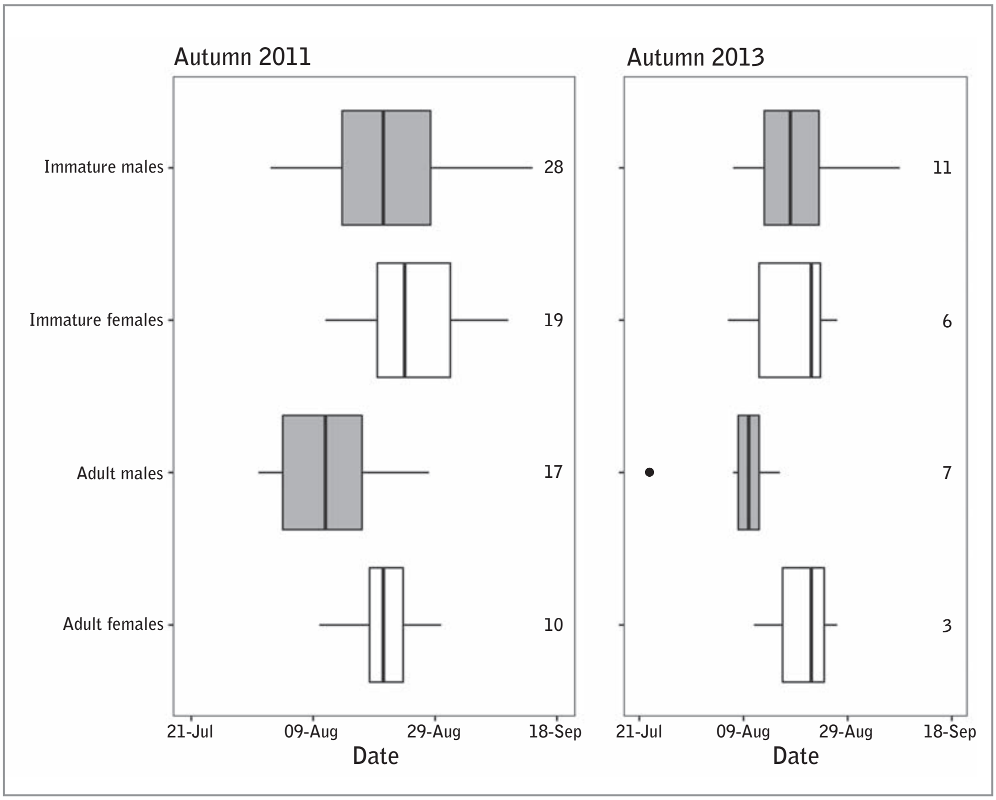
▼ Table 2.9.5

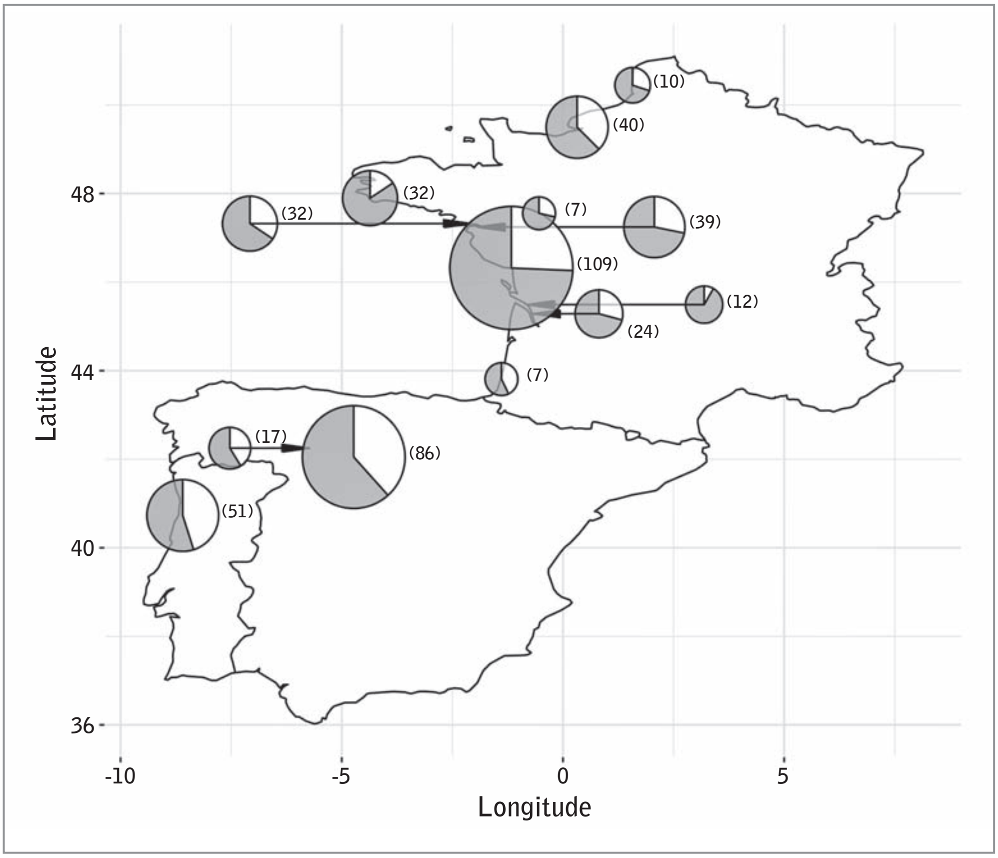
Age ratio and latitude in French ringing stations on the Atlantic coast during post-nuptial migration between 2010 and 2016 (source: O. Dehorter, CRBPO)**. N – number of Aquatic Warblers captured; only stations using the Acrola standard ringing methodology recommended by the CRBPO in France are listed. Importantly, while all the stations are open in August, only two Central-west and West-Brittany ones (Donges, 47.30°N and Tréogat, 47.89°N, respectively) operate from July through to September. Because most birds caught in July are adults, and most birds caught in September are juveniles (see Fig.2.9.4), the lack of ringing effort in these months could bias the adult to juvenile ratios in the Northwest and Southwest.**

Sectors	Latitude (decimal degrees)	Region boundary	% Adult individuals							
			2010	2011	2012	2013	2014	2015	2016	Total
Northwest	51.08 to 48.40	Boundary France-Belgium to bay of Mont-Saint-Michel	8.9 (N=158)	13.5 (N=185)	5.6 (N=142)	8.9 (N=135)	6.4 (N=118)	9.1 (N=263)	2.4 (N=83)	8.5 (N=1,092)
West-Brittany	48.64 to 47.79	West county Finistère	4.7 (N=43)	8.8 (N=34)	6.3 (N=48)	5.7 (N=35)	0 (N=14)	4.2 (N=23)	0 (N=1)	5.5 (N=199)
Central-west	47.76 to 45.69	County Morbihan and south of Ille-et-Vilaine to lighthouse de la Coubre (La Palmyre – county Charente-Maritime)	16.6 (N=157)	21.5 (N=657)	13.0 (N=824)	24.7 (N=384)	28.7 (N=139)	18.4 (N=62)	31.0 (N=113)	19.7 (N=2,406)
Southwest	45.69 to 42.77	lighthouse de la Coubre (La Palmyre –county Charente-Maritime) to boundary France-Spain	22.6 (N=31)	23.4 (N=47)	18.9 (N=37)	14.0 (N=43)	25.0 (N=15)	20.0 (N=16)	28.6 (N=7)	20.5 (N=205)
Total			12.6 (N=389)	19.5 (N=923)	11.9 (N=1,051)	19.3 (N=597)	19.4 (N=286)	11.2 (N=340)	19.1 (N=204)	15.9 (N=3,902)

► Fig. 2.9.6

Sex and age effects on the timing of autumn migration in Aquatic Warblers at a stopover site in the Loire Estuary (Donges, France). The boxes indicate the first and third quartiles, the line inside each box is the median, and the whiskers denote 1.5 of the interquartile range above or below each quartile; the single point is an outlier. Numbers by the boxplots indicate sample sizes (source and copyright: Wojczulanis-Jakubas et al. 2013, 2017)**.**





◄ **Fig. 2.9.7**
Ratio of captured male (grey) to female (white) Aquatic Warblers (all ages pooled) at stopover sites in France, Spain and Portugal. Centres of pies are located at the stopovers. For clarity of the picture, five pies were moved slightly eastwards or westwards and arrows indicate their true coordinates. Sample sizes are given in brackets and the pie size corresponds to the relative sample size (source and copyright: Wojczulanis-Jakubas et al. 2017).

Phenology during post-nuptial migration

During post-nuptial migration, a majority of juveniles and adult females leave the breeding grounds mainly in the last ten days of July, with small and decreasing numbers in early August. Adult males depart earlier than adult females and at least male immatures, before mid-July according to geolocator studies (Salewski et al. submitted), which is reflected by stopover records (Wojczulanis-Jakubas et al. 2013). In the Biebrza Marshes, where studies continued until late August, some birds (mostly females and immature birds) were still detected between 10 August and early September (Kubacka et al. 2014, J. Kubacka pers. comm.). Wojczulanis-Jakubas et al. (2017), in their study of Aquatic Warblers flying over France, Spain, and Portugal, showed that adult males migrate 6.7 days before first-year birds, and that males migrate 3.8 days before females. The day of passage was affected by latitude, and progressed by 1.2 days per one degree of latitude. The early migration of males seems to be associated with the promiscuous breeding system, in which the males are free from parental duties and able to fatten up for migration before the females.

At the Makkumer Zuidwaard site in Holland, Aquatic Warblers were caught from 25 July to 18 September between 1986 and 1996, but most often during the first half of August (van Eerde 1998). However, van der Spek et al. (2017) indicate that the first birds seem to arrive earlier than in the past, especially since the second half of the 1990s, although towards late 1990s the first birds started to arrive slightly later again. The date extremes are now 19 July and 10 October. The first birds are usually trapped at the end of July or the beginning of August. After 20 September Aquatic Warblers become rare. The mean date for trapped birds in Holland is 10 August (van der Spek 2017).

At two main ringing sites in Belgium – Zeebrugge and Veurne – high numbers of Aquatic Warblers were ringed between

1987 and 2017 (N=1,182) using nocturnal tape-luring, and the majority of birds (both adults and juveniles) seemed to migrate before 25 August (N. Roothaert unpubl. data; **Fig. 2.9.3**). The earliest Aquatic Warbler in Belgium was caught on 20 July, the latest one on 30 September. The peak occurred between 11 and 20 August (RBINS).

In Switzerland, 49% of the 45 records of Aquatic Warbler individuals between 1992 and 2009 were observed from the end of July to the end of September without a peak (Vallotton & Piot 2010).

In France, the earliest individual was captured on 8 July 1992 at Trunvel, Brittany, and on 8 July 2014 in the North of the country (CRBPO), though the first individuals were generally captured after 25 July. The maximum migration peak occurred between 10 and 20 August (Le Nevé et al. 2011, Le Nevé et al. 2013a). Afterwards, the migration progressively decreased until the end of September. The latest individual capture was on 16 October 2006 in the Bay of Audierne in Brittany (on its western tip). **Fig. 2.9.4** shows the phenology of the autumn migration in France between 2008-2016 by age class, and appears to show a typical pattern similar to that observed in Belgium, with birds concentrated in August, only single birds in July and September, and a peak of adult migration in the beginning of August. In France, a second passage peak is sometimes observed in mid-September (B. Bargain pers. comm., Foucher et al. 2014). This is also the case in some years in the Netherlands at the Makkumer Zuidwaard site (van Eerde 1998). This is seen as corresponding to late second clutches on the breeding sites.

In Spain, Atienza (2001) mentions a first passage peak between 16 and 25 August, and then a second one from 20 to 29 September. However, Jubete et al. (2006) place the migration peak at Laguna de la Nava, located inland in the Northwest of Spain, between 7 and 23 August. In this site, an analysis of ringing data of 1999-2007 showed that the maximum number of captures occurred each year between 8 and 24 August, the median date of passage was between 14 and 22 of August, the earliest capture was between 17 July and 7 August, and the latest one between 12 and 30 September (**Fig. 2.9.5**). In the Valcavado Stream, between 2004 and 2006 Miguélez et al. (2009) describe a peak of migration between 1 and 15 August for adults, and between 16 and 31 August for juveniles.

In Portugal, the migration peak starts on 21 August and spreads out until 9 September for both adults and juveniles (Neto et al. 2010).

In Morocco, very few birds have been detected so far. In 2009, a ringing effort was made during 15 days in mid-September, at suitable sites where Aquatic Warblers had been recorded in the spring, but no birds were caught (P. Provost pers. comm.). At the same site, the ringing effort started again in early October and the first Aquatic Warblers were captured immediately. There were a few captures in mid-October, although not many (R. Idrissi unpubl. data). Those birds showing much worn plumage could be related to individuals engaged in late (second) broods, which migrate less effectively and do more stopovers (F. Jiguet pers. comm.). The question of Aquatic Warbler occurrence in Morocco is still unclear. The results of the ringing effort in 2009, 2012, 2013, and 2015 do not offer much to understand the occurrence of the species in autumn, and where the birds are after the end of the peak in the Iberian Peninsula at the beginning of September.

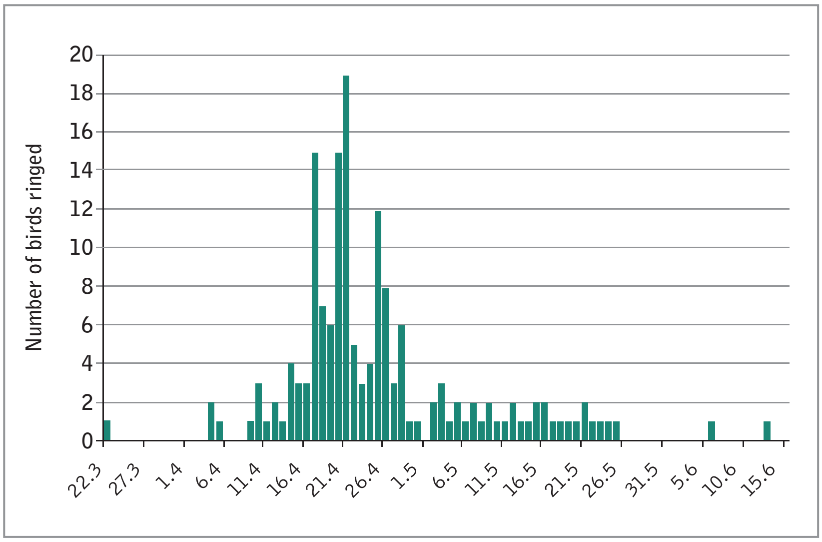
Phenology during prenuptial migration

Aquatic Warbler migration has been reported from February to mid-April in Morocco, with a significant number of exhausted birds observed on 23 March 1972 in Tangiers (Cramp & Brooks 1992).

On the occidental route, in Spain, a few individuals have been recorded as early as the first week of March, but most birds occur from the beginning of April until the beginning of May. A peak is observed from 17 to 21 April (Atienza et al. 2001). In continental France, the earliest bird was recorded on 22 March (Crouzier 2003), but the bulk of migration starts on 10 April and spreads until 3 May (**Fig. 2.9.8**). A peak is observed on 21 April. In 2002, a singing male stopped over on a former French breeding site from 2 to 25 May. InSwitzerland, Cramp & Brooks (1992) point out a brief passage from the second half of April until mid-May. According to Vallotton and Piot (2010), 61% of the 45 Swiss records of Aquatic Warbler individuals between 1992 and 2009 were observed in spring from mid-April to the beginning of May, with a peak at the end of April.

Little information is available from the oriental route. In Corsica, some rare data have been collected in March and the species has been observed until the end of April (C. Jolin pers. comm.), but no bird was captured between 3 and 13 April 2012, during a targeted expedition to search the species in the southern and eastern coastal marshes of this island (Le Nevé et al. 2013c). An individual was recovered on the island of Capraia in Italy in April 1996 (ringed in August 1995 in France; Spina & Volponi 2008). In Slovakia, eight Aquatic Warblers were captured between 18 and 30 April 2008 (Trnka et al. 2008) and the species was captured again in the spring of 2010 (J. Flousek pers. comm.). In the Czech Republic, where the Aquatic Warbler is a regular visitor in spring and summer (129 birds ringed, 108 observed and three found dead from 1946 to 2011; Flousek & Cepák 2013), spring migration peaked in the last decade of April. Two birds from Dzikoje (Belarus) and Supii (central Ukraine) fitted with geolocators crossed the Sahara and the Mediterranean on a straight route, with at least one bird having a longer stopover in April in the region of Slovakia and Hungary, or in neighbouring countries.

The first arrivals of males on breeding grounds, e.g. at the Biebrza Marshes, occur in the last week of April, and mass arrival is observed in the first weeks of May (Dyrcz & Zdunek 1993a). An adult male fitted with a geolocator arrived at its breeding site Dzikoje, Belarus, on 28 April (Salewski at al. submitted).



▲ **Fig. 2.9.8**
Phenology of the Aquatic Warbler in spring migration in France between 1980 and 2017 (N=163, of which 144 were recorded between 2000 and 2017; A. Le Néve unpubl. data**).**

Habitat selection

In Spain and France, conservation projects (Jubete et al. 2006, Le Nevé & Bargain 2009; see also **Box 2.9.2**) and recent ringing and radio-tracking schemes (Foucher 2009, Le Nevé et al. 2009,Foucher et al. 2010, Musseau et al. 2014, Gonin & Mercier 2016) showed that Aquatic Warblers, during their stopovers in autumn, frequent one broad type of habitat: the grassy and more or less wet meadows, within wetlands like estuaries, lagoons, subhalophilous marshes, and also mown meadows along rivers valleys (**Fig. 2.9.9**, **2.9.10**, and **2.9.11**). The vegetation is 0.5 to 1 m high, often with a homogeneous structure with club-rush *Scirpus*, *Schoenoplectus* spp., *Bolboschoenus* spp., *Juncus* spp., and sedges *Carex* spp., and also Poaceae such as *Elymus* spp. (**Fig. 2.9.9**). This kind of habitat hosts larger

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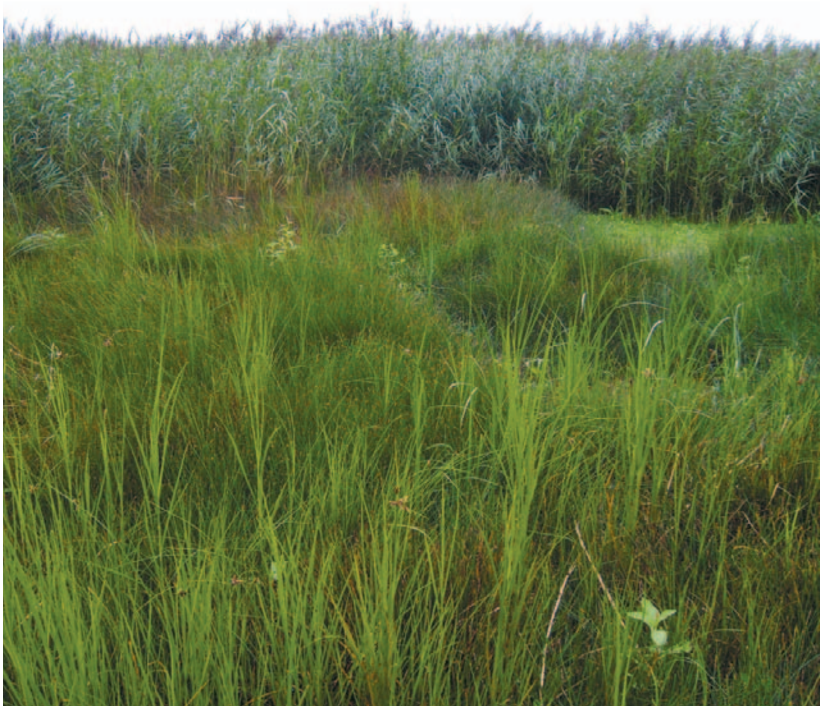


▲ **Fig. 2.9.9**

Stopover habitat in the Seine Estuary, France. Aquatic Warblers forage in wet meadows at the edge of reedbeds. The vegetation structure is similar to the one in breeding and wintering grounds (photo: P. Chevreau, courtesy of P. Provost).

▲ **Fig. 2.9.10**

Subhalophilous meadows of the Baie de l'Aiguillon, Vendée and Charente-Maritime, France, appeared to be some of the most important stopover sites for the species in post-nuptial migration, during the four consecutive seasons of ringing from 2011 to 2014. The habitat used by the species is composed by *Elymus pungens*, *Halimione portulacoides*, **and** *Puccinellia maritima* (photo: J. Gonin).

invertebrates than reedbed (Foucher, 2009), which are selected for by Aquatic Warblers (Kerbiriou et al. 2010, Marquet et al. 2014; see also Chapter 2.4).

Reeds could be used by birds to rest, but some important stopover sites are composed only by subhalophilous meadows without any reeds (such as Baie de l'Aiguillon or the marshes of the Gironde Estuary in France). At Baie de l'Aiguillon, the first bird was observed in August 2010, feeding in a clump of *Halimione portulacoides* (J. Gonin pers. comm.). After four consecutive seasons of ringing from 2011 to 2014, this site, exclusively composed of subhalophilous meadows (**Fig. 2.9.10**), appeared to be one of the most important stopover sites in France for the species (Le Nevé et al. 2013b, Blaize et al. 2014, Gonin & Mercier 2014, 2016). High densities are also hosted by the Brière Marshes, where habitat is a low and diversified reedbed (Marquet et al. 2014), and the Loire Estuary in large stands of club-rush *Bolboschoenus maritimus* mixed with reeds (**Fig. 2.9.12**; Foucher & Dugué 2012, Foucher 2013).

Nevertheless, coastal marshes dominated by homogeneous structures of the Common Reed can be massively used by the Aquatic Warblers in France in autumn stopover sites, probably when they have no other choice. At this kind of site, radio-tracking studies and ringing showed that birds leave reedbeds to forage into available grassy habitats (Bargain 2003, Provost et al. 2010, Foucher et al. 2011, Musseau et al. 2014). This habitat of low grassy structure composed of *Juncus* sp. and *Scirpus* sp. is also the one where the species was captured in pre-nuptial migration, in April 2012 (Le Nevé et al. 2013c) on French Mediterranean coastal marshes (**Fig. 2.9.13**). In fact, the vegetation structure favoured by the Aquatic Warbler at stopover sites is very similar to that in the breeding and wintering habitats.

The Aquatic Warbler that was reported from Libya (see above) rested in a 100 ha wetland surrounded by arable land and grassland east of the town Al Marj (north-east of Benghasi). Habitat type and features of this site are unique in the Cyrenaica

► Fig. 2.9.11
Habitat of the Aquatic Warbler at the autumn stopover site Laguna de la Nava, Spain (photo: C. Zumalacárregui Martínez)**.**

► Fig. 2.9.12
Large stands of club-rush in the Loire Estuary, France, 2012 (photo: J. Foucher)**.**

► Fig. 2.9.13
Subhalophilous meadow without reeds, with *Juncus* **spp.,** *Scirpus* **spp., and even** *Elytrigia juncea* **seems to be the preferred habitat of Aquatic Warblers during spring and autumn migration in France, as at this marsh at Canet-en-Roussillon on the Mediterranean coast in April 2012** (photo: A. Le Nevé)**.**

region. The bird was observed in a shallow pond of c. 5 ha size (probably a sewage pond) with waterfringe vegetation and several bigger islands of *Schoenoplectus* sp. (J. Hering via M. Flade pers. comm.; **Fig. 2.9.14**).

The presence of water above the soil surface also seems to be a crucial parameter. The species is more likely to be caught on the fringe of helophyte vegetation near the water or in wet meadows with a shallow water level from 1 to 20 cm in depth. In August and September, however, in West- and Southwest-Europe, the surface of water can be much reduced in some places and it seems likely that Aquatic Warblers are also able to rest and refuel on temporarily dry patches of wetland. At the Salreu Marshlands, the most important stopover site in Portugal, most Aquatic Warblers are seen and captured on the fringes of extensive rice fields, where water is maintained throughout the summer and autumn, as well as in patches of *Scirpus maritimus* and of *Juncus* or *Typha* (especially if there is water), and less often in pure reedbeds (J. M. Neto unpubl. data).

The home range at stopover sites was studied in five different stopover sites in France: Trunvel in 2001 and 2002 (A. Le Nevé unpubl. data), the Seine Estuary in 2008 (Provost et al. 2010), the Gironde Estuary in 2010 and 2011 (Musseau et al. 2014), the Loire Estuary (Foucher et al. 2011), and Baie de l'Aiguillon in 2014 (Gonin and Mercier 2016). At the Seine Estuary, 15 birds were radio-tracked and analysed, showing an average area range

2.9

▲ **Fig. 2.9.14**
The habitat in which an Aquatic Warbler was observed in Libya (near Al Marj, Cyrenaica) on 27 May 2008 was a pond with water-fringe and open water patches of *Schoenoplectus* **sp.** (photo: J. Hering).

of 9.05 ±11.04 ha and a daily range size of 4.24 ±3.77 ha. At the Gironde Estuary, of the 17 birds radio-tracked, 14 (eleven juveniles and three adults) yielded data allowing to asses the home range. The average Minimum Convex Polygon (MCP) surface (corresponding to the average area explored by monitored birds) was 6.64 ±2.64 ha, whereas the average area actually exploited (core areas, i.e. those with high density of fixes) was 1.00 ±0.21 ha. The average ratio between individual core areas and the polygon containing all these core areas (C part) was 0.32 ±0.06, which means that there is a relatively high fragmentation of the ground exploited by the individuals. At Donges in the Loire Estuary ten birds were radio-tracked for an average of five days (range 2-14), showing an MCP of 6.47±5.32 ha and a core area of 2.59±2.05 ha, with a C part of 0.53±0.39. In addition, many recoveries of Aquatic Warblers were made within 50 km of the ringing location between 1-10 days after the ringing date, which indicates that the birds could use several wetlands, when they are close, as one global migratory stopover (Foucher et al. 2014). At Baie de l'Aiguillon, nine birds were radio-tracked and analysed, showing an average surface of 8.61 ±4.34 ha. In Spain, two birds were radio-tracked at the Txingudi Estuary in August 2011 to assess their home range during stopover (Andueza et al 2014). One of the surveyed individuals was tracked during less than 24 hours, whereas the other was followed for ten days. The home range (kernel area 95%) of this individual covered 1.46 ha with a MCP of 3.66 ha.

Threats

The destruction of wetland habitats was most certainly the greatest threat to the species' migration route during the 19th and 20th century in Europe. Nowadays, there are still some large development projects on wetlands (e.g. in the Seine Estuary and Loire Estuary) that threaten migration sites. In the Loire Estuary, a project to establish a Natural Reserve failed in 2016 because of local political pressure against it.

A recent example is Veurne (Belgium), where numbers of ringed Aquatic Warblers have decreased dramatically since 2007. The ringing site is situated on a 50 ha estate of decantation basins from a sugar factory that was abandoned in 2006. Before the plot was sold, substantial amount of water was drained from the lakes and marshes, causing a rapid change of habitat with an invasion of nettles, thistles, brambles, and Bittersweet Nightshade (*Solanum dulcamara*) into the reedbeds and marshes (N. Roothaert pers. comm.). Fortunately, during the winter of 2016-2017, the new owner cleared the remaining 17 ha of the nature area of old reedbeds, creating a homogeneous reedbed with an area of 4 ha. This resulted in 87 individuals ringed in 2017, which was the best year ever on this site. Most wetlands used during migration are now classified as Natura 2000 sites, and so it is now easier to protect them against such destructive projects.

At the Gironde Estuary, Musseau et al. (2018) highlighted the threats from global change that may impact coastal stopover sites exploited by the Aquatic Warbler. Between 2000 and 2016, along the 24.5 km of the mesohaline region of the north bank of the estuary, there was an average shore retreat of 14.74 ±0.50 m over the period studied. This corresponds to a loss of 49.96 ha of intertidal wetlands (i.e. 2.04 ha per km of coastline) and on average more than 30 m for 42% of the coastline. This erosion dynamics, explained by a significant perturbation of the estuary's hydro-sedimentary dynamics (due to decreases in freshwater discharges and increasing tidal influences associated with a rise in sea level), reveals the threats posed by global change on coastal stopover sites exploited by the Aquatic Warbler and particularly on estuarine stopover sites, which are especially sensitive to perturbation of the hydro-sedimentary dynamics. These findings highlight the importance of developing conservation strategies for habitats exploited by species such as the Aquatic Warbler, integrating the potential key roles of inshore coastal areas (by means of reconnection – at least partial – with inland polders), in order to compensate for losses of habitats due to the ongoing and forthcoming effects of global change (Musseau et al. 2018).

At several coastal marshes in northern Iberia, Arizaga et al. (2013) highlighted the threats that may impact coastal stopover sites used by the Aquatic Warbler. Reedbeds in the stopover sites could be negatively affected by invasive exotic plants, which outcompete native vegetation, such as the Saltbush *Baccharis halimifolia*. The invasion of the Saltbush led to a remarkable change in bird assemblage, promoting species typical of woodland habitats. Compared to Saltbush habitats, Sedge Warblers *Acrocephalus schoenobaenus* using native reedbeds departed with a higher fat load and had a higher fat deposition rate and longer stopovers. Therefore, the replacement of reedbeds by Saltbushes should be regarded as a factor with potential negative consequences for the migratory bird species associated with this habitat, including the Aquatic Warbler.

In inland Spain, mowing meadows along river valleys has led to their destruction over the recent years, mainly in the areas that were converted to poplar plantations (*P. populus* x *P. canadensis*) and corn fields. Currently, land consolidation and drainage plans are likely to intensify agricultural use.

In Morocco, the tourist industry poses a threat to the wetlands due to intensive urbanisation, as well as invasive flora species, such as *Spartina densiflora* at Merja Zerga (Le Nevé et al. 2013c). Invasive species of plants could also be an important threat in France, with *Ludwigia peploides*

Box 2.9.2

EU LIFE projects on Aquatic Warbler conservation in Spain and France

ARNAUD LE NEVÉ

Two large EU LIFE conservation projects targeting a better understanding and conservation of Aquatic Warbler migration sites were implemented in Spain and in France.

Conservation of the Aquatic Warbler
in the Nava-Campos SPA (Spain)
Number: LIFE02 NAT/E/008616
Beneficiary: Fondatión Global Nature
Duration: 2002-2006
Budget: 1,217,240 €
Website: www.fundacionglobalnature.org

Conservation of the Aquatic Warbler
in Brittany (France)
Number: LIFE04 NAT/FR/000086
Beneficiary: Bretagne Vivante – SEPNB
Duration: 2004-2009
Budget: 965,000 €
Website: www.life-phragmite-aquatique.org

The main outcomes of both projects include:

- improved habitat conservation by enlargement of the Aquatic Warbler habitat in Spain and the purchase of 53 ha of marshes in France;
- experimental restoration of foraging habitat by water and vegetation management on three sites totalling 230 ha in France;
- increased scientific knowledge about the Aquatic Warbler and its habitat e.g. by a diet study in France and international final conferences in Palencia (Spain) in 2005 and Quimper (France) in 2008;
- awareness-raising among wetland managers to learn about the conservation requirements of the species during migration by publications, films etc.;
- a regional conservation strategy and a new National Action Plan 2010-2014 in France;
- a follow-up project 'Wetland restoration and management: Canal de Castilla Special Protection Area LIFE06 NAT/E/000213' 2006-2010 in Spain, implementing a programme for the recovery, management, and monitoring of 35 small wetlands which also improves conditions for migrating Aquatic Warblers.

In Spain, another project (LIFE16 NAT/ES/000168) received funding recently, 'Habitat restoration for the spring and autumn migration of the Aquatic Warbler in the Iberian Peninsula'. The main objectives of the project are to:

- encourage traditional management of target wetland vegetation, extend the area of rare or disappearing habitats and thus increase the availability of stopover sites along the species' migratory routes in Spain;

►

and *Ludwigia grandifolia* now well set up on wet meadows of major stopover sites such as the Lac de Grandlieu (A. Le Nevé unpubl. data) and the marsh of Grande Brière (M. Marquet pers. comm.) and/or the marshes of Mazerolles (Latraube 2013). In France, the threat also comes from the abandonment of traditional agricultural practices in the wetlands (summer mowing and extensive pasture), which used to maintain vegetation succession favourable to the foraging of Aquatic Warblers. This abandonment results in a change in vegetation, which is broadly overgrown by reeds and then by willows causing the disappearance of the foraging habitats of the species (Le Nevé et al. 2009). This situation is very similar to the main threat on breeding grounds, i.e. abandonment of mowing by farmers and the resulting successional overgrowth (see Chapter 3). On the other hand, intensive mowing and pasture on wet meadows (e.g. in the Loire Estuary at Donges in 2013; Foucher 2013) can also drastically reduce the habitat of the species, even the reedbeds, when the summer is hot and dry, and when farmers search for grass for their cattle (F. Latraube pers. comm.).

The major stopover sites in Portugal are located in Natural Reserves or in Natura 2000 sites (Neto et al. 2010), but no specific management concerns the Aquatic Warbler, despite its globally-threatened status. The Salreu Marshlands in particular are threatened by an increasing dryness during the summer months, as well as the progressive abandonment of the extensive rice fields, which are occasionally replaced by corn fields rather than by other Aquatic Warbler habitats.

Aquatic Warblers are dependent on a sufficient number of good quality stopover sites, mainly along the Atlantic coast of Southwest-Europe and Northwest-Africa. While key sites in Europe now seem to be reasonably well protected, it is likely that wetland sites along the coast of Morocco, western Sahara and Mauritania are under intense pressure and might be deteriorating as stopover sites for the species (Zwarts et al. 2009, Foucher et al. 2013).

Conservation

The migration strategy of the Aquatic Warbler relies on a fragile balance between its physical capacities and the availability of stopover sites. This balance can easily be jeopardised by exterior disruptions, such as the destruction of stopover sites. For this reason, two large conservation projects funded by the EU LIFE Programme were, or still are implemented in Spain and in France (**Box 2.9.2**). They have focused on documenting and understanding the migration of the species and on testing methods of restoration of the foraging habitats on one site in Spain and on three sites in France.

In France, the species is strictly protected. A National Action Plan for 2010-2014 was taken over from the LIFE Project and is being implemented in all of the 200 stopover sites that are now recognised in the country. Its total annual budget is about 100,000 Euro. The National Action Plan has just been renewed from 2018 to 2028.

The Aquatic Warbler is also strictly protected in Spain; it is included in the National Catalogue of Endangered Species (Royal Decree 139/2011) in the category 'of special interest', and thus the Autonomous Communities must incorporate this in their management plans for the species. In the Red Data Book, the species is listed as Vulnerable in accordance with IUCN criteria. The majority of the areas where it is regularly recorded are protected, including Ramsar sites and Special Protection Areas (SPAs), National Parks (Doñana) and Protected Natural Areas of the Autonomous Communities.

Box 2.9.2 contd

- increase local knowledge of the species and awareness about the benefits of recovering traditional management of vegetation;
- establish a national strategy for the conservation of the Aquatic Warbler in Spain, as well as specific CAP EU rural development agri-environmental programmes, to ensure legislative and financial measures to enable the implementation of management plans sustainable in the long term.

2.10 Wintering

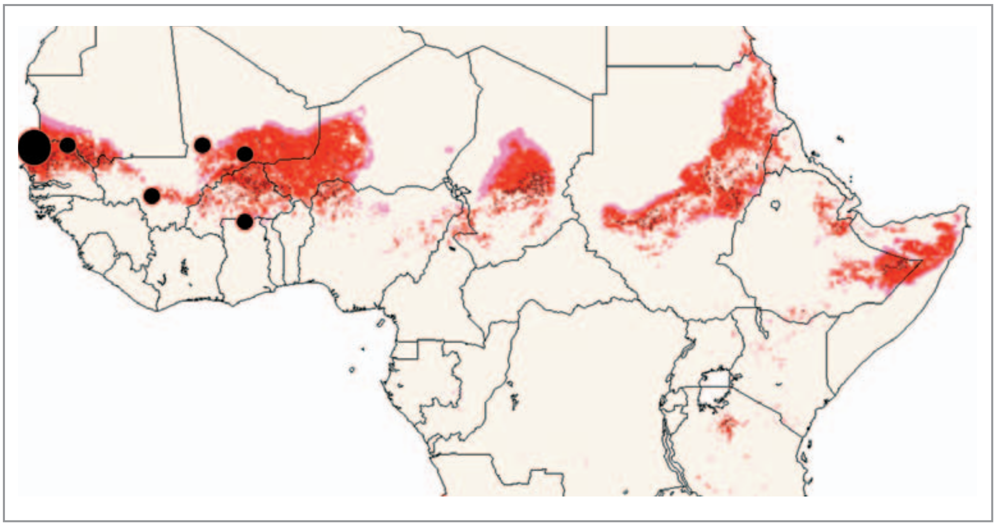
COSIMA TEGETMEYER, JULIEN FOUCHER & MARTIN FLADE

Although much is known about Aquatic Warbler breeding grounds and stopover sites in the western Palaearctic, the same cannot be said of the species' African wintering grounds. While the protection and active management of key breeding grounds is developing and showing good results (see Chapter 2.2), a fundamental threat to the survival of this habitat specialist could still exist or develop on the wintering grounds, and potentially undermine the conservation success in the breeding grounds. Africa is a vast continent with a very low density of ornithological observers or research institutions. Unobtrusive species, such as the Aquatic Warbler, frequently go unnoticed, and therefore our understanding of wintering and stopover areas used by the species in Africa is limited.

Desk studies on Aquatic Warbler wintering grounds

In order to narrow down the possible Aquatic Warbler wintering grounds, all the records of Aquatic Warblers in Africa that were available at the time were compiled (Schäffer et al. 2006). For the months of November to January, the Aquatic Warbler had been recorded in four countries: Ghana (one record), Mali (five), Mauritania (four), and Senegal (six). All the available information pointed to autumn and spring migration through Northwest-Africa and wintering in western Sub-Saharan wetlands. In a further approach, areas with suitable conditions for the occurrence of wintering sites within Sub-Saharan West-Africa were identified with statistical modelling, whereby land use and climate data were analysed to predict the probability of the occurrence of Aquatic Warbler habitats (Walther et al. 2007; **Fig. 2.10.1**).

Furthermore, a study on stable isotopes in tail feathers of adult Aquatic Warblers – which are known to be grown on wintering grounds – examined whether different breeding populations in Europe used the same wintering grounds in Africa (Pain et al. 2004). This study provided some insight into the latitudinal range of likely moulting habitats, but some of the results have to be considered with caution, since a subsequent study did not confirm the hypothesis that different breeding populations winter in different areas in Africa (Oppel et al. 2011). To explore where moulting and wintering areas of Aquatic Warblers may be located in West-Africa, their feather isotope ratios were compared to feather isotope signatures of two resident African surrogate species (the Wind-



► **Fig. 2.10.1**
Results of the statistical modelling exercise using vegetation and climate data to predict the probability of occurrence of Aquatic Warblers (Walther et al. 2007), and winter (November-January) records (black dots) of Aquatic Warblers in Africa (Schäffer et al. 2006).

ing Cisticola *Cisticola galactotes* and the Grey-backed Camaroptera *Camaroptera brachyura*). Because Sub-Saharan wetland habitats used by Aquatic Warblers contain plant species with different photosynthetic pathways, the isotopic variation in feathers grown within a single habitat patch can be much larger than the variation between different regions. The use of feather isotope ratios alone therefore does not appear to be a promising tool to find previously undiscovered wintering areas of Aquatic Warblers.

The combination of historic observations, predictive bioclimatic modelling, and isotopic inference led to the conclusion that major Aquatic Warbler wintering sites are most likely situated in the estuary of the Senegal River, as well as in the Inner Niger Delta in Mali. At the conference of signatory parties of the Memorandum of Understanding (MoU) under the Convention on Migratory Species of Wild Animals (Bonn Convention, CMS) in 2006 in Germany, the BirdLife International Aquatic Warbler Conservation Team (AWCT) highlighted the identification and study of wintering sites as being of highest priority (BirdLife International & CMS 2009). This priority was confirmed in 2015 at the 3rd Meeting of Signatories of MoU. The research and conservation of African stopovers and wintering sites is now one of the four main objectives of the International Action Plan for conserving the Aquatic Warbler (CMS 2015).

▲ **Fig. 2.10.2**
Team of the 2007 Senegal expedition – 44 people from three African and 11 European countries (photo: V. Salewski).

◄ **Fig. 2.10.3**
Indega Binda looking at one of the first Aquatic Warblers caught during the 2007 AWCT expedition in Senegal (photo: M. Flade).

First Senegal expedition 2007

Thanks to substantial support from the British government (DEFRA), the CMS Secretariat in Bonn, the Royal Society for the Protection of Birds (RSPB), and the European Commission through a LIFE project in France, it was possible to make an initial expedition in January and February of 2007 (**Fig. 2.10.2**, **2.10.3**), in order to identify the Aquatic Warbler wintering grounds in the most promising site – the estuary of the Senegal River in Northwest-Senegal. This expedition was organised by the AWCT. The responsible authorities in Senegal, namely the administration of the Djoudj National Park (see **Fig. 2.10.4** and **Box 2.10.1**) and the local Biological Station headed by Ibrahima Diop, ensured flawless organisation on site. Ringing work was organised by the French AWCT partner 'Bretagne Vivante'. The expedition was successful, identifying large open grassy wetlands located within the Djoudj National Park and its buffer zone as a major wintering site. In total, 56 Aquatic Warblers were caught at this site during the expedition. Preliminary estimates of the density of wintering Aquatic Warblers in suitable habitats at the Djoudj ranged between 0.5 and 1.6 birds per ha. According to the initially estimated area of suitable habitat (4,000-10,000 ha with strong seasonal and inter-annual fluctuations) the Djoudj area was assumed to hold between 10% and >50% of the global population during the non-breeding season (Flade et al. 2011).

2.10

Box 2.10.1
The Djoudj National Park

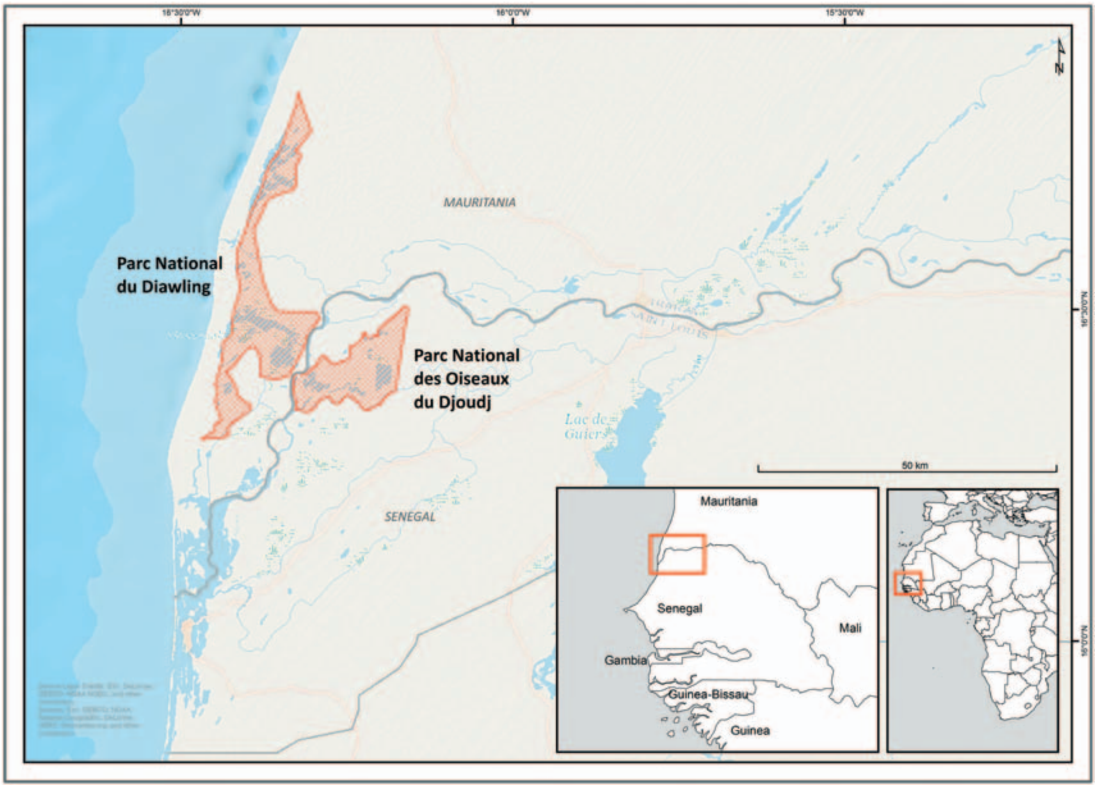
COSIMA TEGETMEYER

Established in 1971 and listed as a Ramsar site since 1977, the Djoudj National Park is situated in the centre of the Senegal River Delta in the Northwest of Senegal, close to the border with Mauritania (**Fig. 2.10.4**). Declared as a World Natural Heritage Site in 1981, it is an important wintering site for Palaearctic migrants, such as the Sedge Warbler *Acrocephalus schoenobaenus*, the Sand Martin *Riparia riparia*, and the Garganey *Spatula querquedula*, as well as a breeding habitat for numerous African water bird species. It extends over 16,000 ha and covers 5% of the Delta. The climate is semi-arid and the annual precipitation of 200-250 mm is limited to the rainy season from July until September (Dia et al. 2002). The Park and its buffer zone comprise seasonal floodplains interspersed with open water bodies, lakes, and old oxbows of the Senegal River. Once a natural part of the floodplain, since the conversion of the largest parts of the Delta into a diked freshwater reservoir in 1992, it is nowadays flooded artificially with water from the Senegal River during the rainy season. The water evaporates completely during the dry season. Apart from a few single trees and bushes, the floodplain is dominated by grassy vegetation, with species such as *Scirpus littoralis*, *Scirpus maritimus*, *Eleocharis mutata*, and *Sporobolus robustus*, as well as Red Rice (*Oryza longistaminata*; **Fig. 2.10.5**). In the last few decades, invasive species, such as *Typha australis* have spread in the protected sites and today cover vast areas of the floodplains. In addition, areas in the buffer zone have been converted to rice fields (**Fig. 2.10.6**).

Sites and habitats in the Djoudj area (Senegal)

Following the discovery of the wintering site in the Djoudj area (**Box 2.10.1**), a PhD project (2008-2014) at Greifswald University (Germany) brought more insight into population density and the area of suitable habitat at Djoudj, as well as into key ecological characteristics of the wintering habitat. Fieldwork was conducted during periods of 0.5-2.5 months in four European winters. To determine when and where Aquatic Warblers used a given site, and to identify the relevant biotic and abiotic site conditions, the presence of Aquatic Warblers was confirmed by mist-netting using the rope-dragging method. Some captured Aquatic Warblers were equipped with radio transmitters. The study confirmed the presence of Aquatic Warblers in the Djoudj area between mid-December and the end of March (Tegetmeyer et al. 2012). The con-

▼ **Fig. 2.10.4**
Location of the Djoudj and Diawling National Parks in the Senegal Delta (map prepared by Cosima Tegetmeyer, based on the Freytag & Bernt map of Gambia and Senegal 2009).



nection between the wintering ground in the Djoudj area and the breeding ground in eastern Poland was confirmed by a female Aquatic Warbler that was colour-ringed in the Djoudj and recovered as a breeding bird in the Biebrza Marshes (Poluda et al. 2012). During the winter, Aquatic Warblers used a home range of 3.9 ha (s.d. ±1.9) on average, which is shared with other individuals and species. No territorial behaviour was observed in the winter quarters (Arbeiter & Tegetmeyer 2011). The moult of remiges was observed under natural conditions for the first time and it was confirmed that the Aquatic Warbler undergoes a complete moult on its wintering grounds, following the typical sequence of passerine moult (Tegetmeyer et al. 2012).

In the Djoudj region, Aquatic Warblers were found in shallowly inundated vegetation with dominant stands of *Oryza longistaminata*, *Eleocharis mutata*, *Scirpus maritimus*, *S. littoralis*, and *Sporobulus robustus*, interspersed with small (1-2 m²) areas of open water. These herbaceous species form homogenous wetland vegetation at a height of c. 0.6-1.5 m, with a coverage of 80% to 100%. Red Rice (*Oryza longistaminata*) may provide the most suitable habitat conditions, as suggested by the very high density of Aquatic Warblers at sites dominated by this species. Pure stands of Southern Cattail (*Typha domingensis*) are avoided. The water level in the habitat areas varies between 0 (humid soil) and 40 cm above the ground. Constant inundation seems to be essential, as Aquatic Warblers were never encountered in dry parts of the study area. There was 4,729 ha of potential Aquatic Warbler habitat within the study area (Tegetmeyer et al. 2014). We estimated the density of the Aquatic Warbler population in the study area to range between 0 and 2.26 individuals per hectare, with a total population size of 776 individuals (95% credible interval 260-4,057 individuals). Hence, we concluded that 1.1-3.8% (with the 95% credible interval of 0.37-19.8%) of the global Aquatic Warbler wintering population, assuming the range of 20,400-68,900 wintering individuals, are found in the Djoudj area (Tegetmeyer et al. 2014). Management proposals derived from this research were incorporated into the Management Plan of the Djoudj National Park 2014-2018.

Other suitable habitats were found in the surroundings (up to 30 km) of the Djoudj, in the Ndiaël Reserve and the Trois Marigots area. The search took place in 2008 (AWCT, Flade 2008), 2013 (J. Foucher pers. comm.), and 2016 (Tegetmeyer et al. 2016). No Aquatic Warblers could be detected, but several areas with habitats looking suitable for the species were identified.

▲ **Fig. 2.10.5**
Typical Aquatic Warbler habitat with waist-high Red Rice *Oryza longistaminata* **in the buffer zone of the Djoudj National Park** (photo: C. Tegetmeyer).

▲ **Fig. 2.10.6**
Rice plantation at the border to the Djoudj National Park (photo: C. Tegetmeyer).

2.10

Sites and habitats in Mauritania

Diawling National Park

Located only 3 km away from the Djoudj National Park (**Fig. 2.10.4**), the Diawling National Park protects floodplain habitats that are similar to those found in the Djoudj, and was therefore considered as a potential stop-over or wintering site. The Diawling is found on the western side of the Senegal River, opposite to the Djoudj, and was created in 1991, following the construction of the Diama Dam on the Senegal River in 1986. Covering 56,000 ha, it includes several basins fed by sluices, which allow controlled water supply to the floodplain from the river. This has led to the development of vast, low-flooded (between 5 and 50 cm) wetland meadows, consisting mainly of *Bolboschoenus maritimus*, *Sporobolus robustus*, *Oryza barthii* and *Schoenoplectus lacustris*, with tufts of *Typha* sp. (**Fig. 2.10.7**, **2.10.8**). The Aquatic Warbler was observed in the Diawling National Park once in 2006 (Benmergui and El Abidine Ould Sidatty pers. comm.). However, during an intensive search in mid-January 2008 (Flade 2008) and late January 2010 (Salewski & Seifert 2010) within the Park and in adjacent areas along the valley of the Senegal River, no Aquatic Warblers could be detected, probably because the area was already too dry at that time. Between 2010 and 2014, the French association ACROLA set up a partnership to study the wintering of reed-bed passerines, including the Aquatic Warbler. During a total of 60 ringing-days over three winters in the Diawling in suitable Aquatic Warbler habitats, more than 3,000 trans-Saharan wetland birds were ringed, but no Aquatic Warblers were found. It is of utmost importance to find an explanation for the absence of the Aquatic Warbler in the Diawling National Park. The distribution of bird species in the Diawling is similar to that observed in the Djoudj National Park (Foucher et al. 2013) and, thanks to the ringing work carried out in parallel in the latter, many movements of Sedge Warblers could be documented: some birds ringed early in winter in the Diawling were recovered at the end of winter in the Djoudj (Tegetmeyer et al. 2012) and birds ringed in the Djoudj were recovered the following year in the Diawling at the beginning of winter (Foucher et al. 2013). One reason for these movements could be that the grassy marshes of the Diawling basins dry up between mid-January and mid-February, and some of the birds that no longer find suitable habitats there continue to winter in the Djoudj, where water is kept artificially longer for the avifauna. Understanding the reasons behind the lack of the Aquatic Warbler in the Diawling National Park could allow wetland management in the Park to be adjusted to suit the species and, if it is effective, to greatly increase the potential suitable area for the species in the Senegal Delta.

▼ **Fig. 2.10.7**
Wet grassy marshes in the Diawling National Park, December 2013 (photo: J. Foucher).

▼ **Fig. 2.10.8**
Potential wintering habitat in the Diawling National Park, Mauritania (photo: F. Tanneberger).

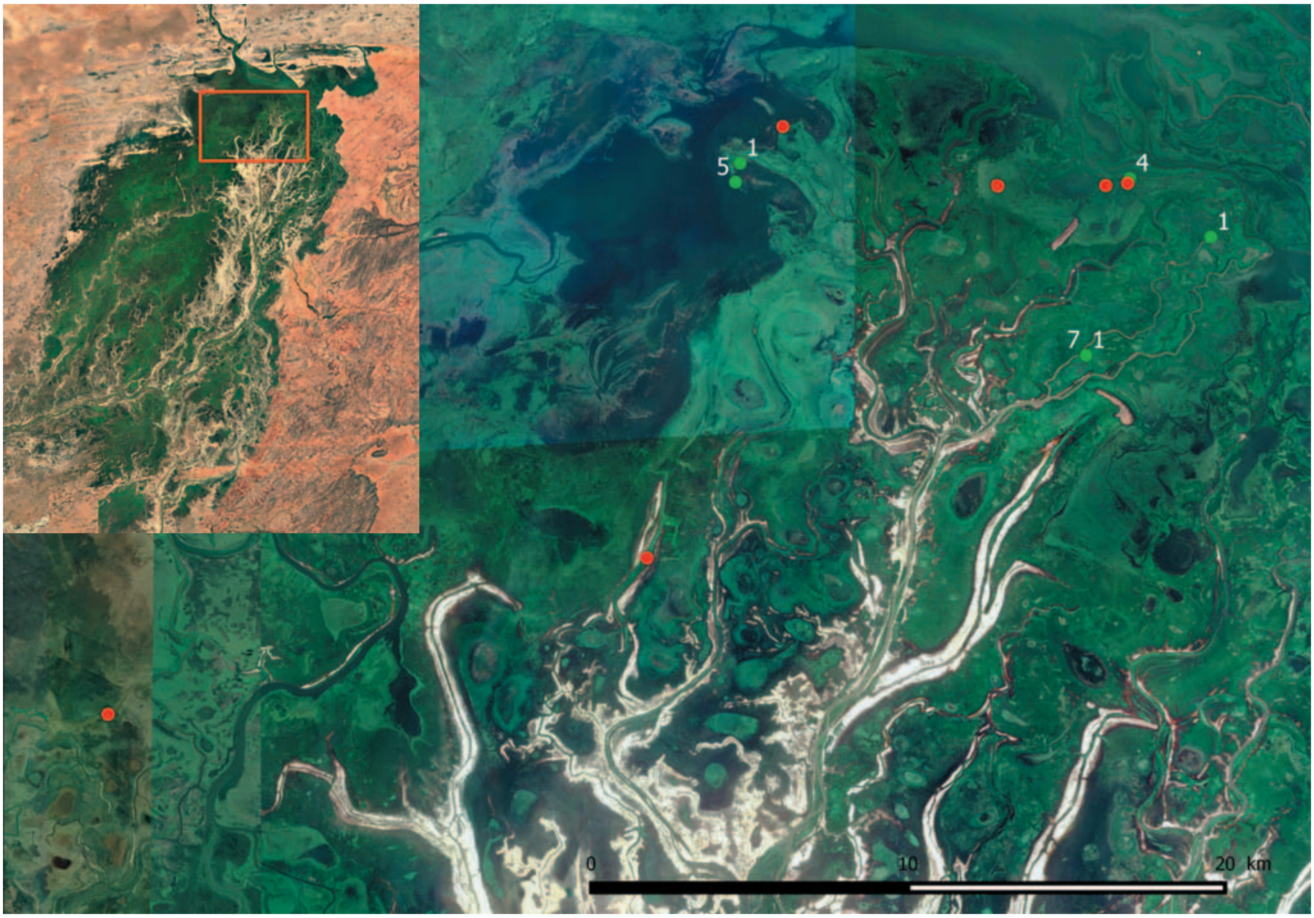
Inland wetlands

A survey of the wetlands at the boundary between the Saharan desert and the Sahelian steppe, conducted by the GTZ (now GIZ - German International Development Agency) in 2001 identified 244 wintering sites for wetland birds (Shine 2002). Thanks to the 2010-2014 partnership between the Diawling National Park and ACROLA, 20 sites across Mauritania that appeared suitable for the Aquatic Warbler were visited, of which only five turned out to actually be potentially suitable. Ringing was conducted in these five wetlands and the Aquatic Warbler was found in two of them (Foucher et al. 2013): M'Barwadji (**Fig. 2.10.9**) (GPS: 16.68672; 15.11056, 0.8 km²), where one bird was caught in January 2011, but none were found in December 2012 and December 2013, when the wetland was completely dry; and Guimi (GPS: 17.45962; 13.22361, 3 km²), where two birds were caught in January 2011, none were found in December 2012, when the site was completely dry, and one bird was caught in December 2013. These two wetlands seem ecologically similar: they are slightly flooded (between 0 and 15 cm), with vegetation in a high herbaceous layer with *Bolboschoenus maritimus* and forest with *Acacia nilotica*, the density of which increases with proximity to the edge of the wetland. Both contain deeper areas where *Nuphar lutea* and *Nymphaea alba* develop. These wetlands are highly dependent on annual rainfall and can completely disappear in some years (**Fig. 2.10.10**). The distribution of ringed species is different there than in the Djoudj National Park or the Inner Niger Delta, and shows a higher proportion of the Bluethroat, the Grasshopper Warbler and the Savi's Warbler, which were caught while moulting (Foucher 2013). These wetlands are the first possible stopovers for migratory birds after crossing the Sahara. In this period (September-October), they are flooded to the maximum following the rainy season in July-August, which enables the growth of vegetation.

▲ **Fig. 2.10.9**
Wetland of M'Barwadji, January 2011 (photo: J. Foucher).

▲ **Fig. 2.10.10**
Wetland of Guimi, top: January 2011; bottom: December 2011 (photo: J. Foucher).

2.10



▲ **Fig. 2.10.11**
Mist-netting sites in the Inner Niger Delta. Places where Aquatic Warblers were captured are in green and the number of birds caught is given.

Sites and habitats in Mali

In Mali, it was suspected for many years that the Aquatic Warbler winters in the Inner Niger Delta (Schäffer et al. 2006, Zwarts et al. 2009, Buchanan et al. 2011, Flade et al. 2011, Oppel et al. 2011; see also **Box 2.10.2**), and some individuals had already been recorded there (Schäffer et al. 2006, Zwarts et al. 2009). However, it was not until February 2011 that wintering was proved through the capture of 13 individuals during a research mission organised and supported by the ACROLA association (Foucher et al. 2013). One of these birds was ringed on 9 February 2011 at the Mayo Dembé near Kofel, and recaptured on 1 June 2011 in the Supii Mire in central Ukraine. This was the first proof of connectivity between breeding and wintering sites (Poluda et al. 2012). In total, four expeditions were carried out from 2009 to 2014, one each winter. Mist-netting operations were carried out at 15 different sites, resulting in 19 Aquatic Warblers being caught at six sites (**Fig. 2.10.11**). Although the birds were captured in sites with apparently comparable vegetation, Bourgou *Echinocloa stagnina* and Dideré *Vossia cuspidata*, these species do not define the preferred habitat for the Aquatic Warbler in the Inner Niger Delta. The Aquatic Warbler seems to mainly use the weakly flooded 'bourgoutières', with 25 cm to 1 m of water. Seven individuals were caught where they were not expected: on dry, 30 to 70 m wide banks with small wet depressions and less than 10 cm of water. The vegetation of this drier zone is also more diversified: Bourgou and Dideré are still there, but associated with Poro *Aeschynomene nilotica*, *Polygonum senegalense,* and *Mimosa pigra* (**Fig. 2.10.12**). This varied flora attracts a high density of insects, mainly locusts, a group well-appreciated by the Aquatic Warbler (Kerbiriou et al. 2010). Knowing that the Aquatic Warbler was the main species among trans-Saharan migrants caught in this zone, it can be hypothesized that these quickly drying, topographically varied environments with heterogeneous vegetation are some of the most preferred habitats for the species in the Inner Niger Delta (Foucher 2013). The ACROLA also explored another area, called 'Office du Niger', near Nioro. This vast wetland is almost entirely developed for rice cultivation. No suitable habitats could be detected: temporary wetlands are cultivated and perennial wetlands, often artificial reservoirs, are invaded by invasive plants, such as *Typha* sp. or *Salvinia molesta*. The apparently suitable areas, as predicted by desk studies from remote sensing (Buchanan et al. 2011), are in fact floating mats with sparse vegetation, unfavourable for the Aquatic Warbler.

Desk studies and field search for further wintering areas

Following the expeditions to the Djoudj and Diawling National Parks in 2007/2008, two basic analyses aimed at identifying additional sites that might be used by wintering Aquatic Warblers have been carried out. Based on vegetation data from the Djoudj area, unsupervised classification of a LANDSAT satellite image (resolution 30 m) covering about 141 km^2 of the surroundings of Djoudj identified two habitat types that appeared to be occupied by birds, although the paucity of data makes interpretation speculative. This analysis also identified areas of the same habitat types in surrounding areas. Further survey efforts could be targeted to these areas to determine whether they hold Aquatic Warblers, while also verifying whether other areas are indeed unsuitable. At a coarser resolution (1 km), remote sensing data based on Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index (NDWI) were used to identify sites within the complete putative winter range that were similar to the conditions found in Djoudj. By identifying areas with similar characteristics to those in which Aquatic Warblers are known to occur, a map showing specific areas to which further field surveys could be targeted was produced. Some 1,100 km^2 of the surveyed area are potentially suitable, located in the Inner Niger Delta, along and away from theNiger River in Mali, and in southern Mauritania (Buchanan et al. 2011, see **Fig. 2.10.13**). Based on the results of all the studies conducted to date, further wintering grounds are expected also at some sites along the Senegal River and at wetlands in southern Mauritania.

Box 2.10.2
Inner Niger Delta

JULIEN FOUCHER

Classified as a Wetland of International Importance by the Ramsar Convention in 2004, the Inner Niger Delta in Mali, an inland delta of the Niger River, is one of the largest wetlands in Africa. It is an area of fluvial wetlands, lakes, and floodplains in the semi-arid Sahel area of central Mali, just south of the Sahara desert. The flooded area varies between 7,000 km^2 and 35,000 km^2, depending on the annual rainfall (Zwarts et al. 2009). The Inner Niger Delta not only stands out because of its size, but also because of its hydrological dynamics. Between July and December, the water rises by more than 6 m in wet years, and declines by the same amount in the subsequent months. In extremely dry years, however, the flood level rises by only 3 m. The water level also changes spatially. When it starts to rise in the southwestern part of the delta in July, the plains in the Northeast are still dry. By the time the northern plains become flooded, two months later, the water level is already receding in the south. The area covered by water at any one time amounts to 25,000 km^2. Such a large flood extent is only possible when the combined inflow of Niger and Bani rivers, the major tributaries, exceeds 55 km^3 in the rainy season. In most years, the inflow is smaller. During the disastrous drought in 1984, the inflow was only 15 km^3, and the flood extent did not exceed 5,500 km^2 (Zwarts 2010). The Inner Niger Delta is covered mainly by large herbaceous helophytes adapted to high variations of water level. The local name of these grasses, with stems up to 6 m, is Bourgou (Zwarts et al. 2009). This plant forms very dense, gigantic meadows in which it is difficult to move. The height of above-water vegetation is not very large, because these plants follow the water table and collapse to form an inextricable, flooded jungle.

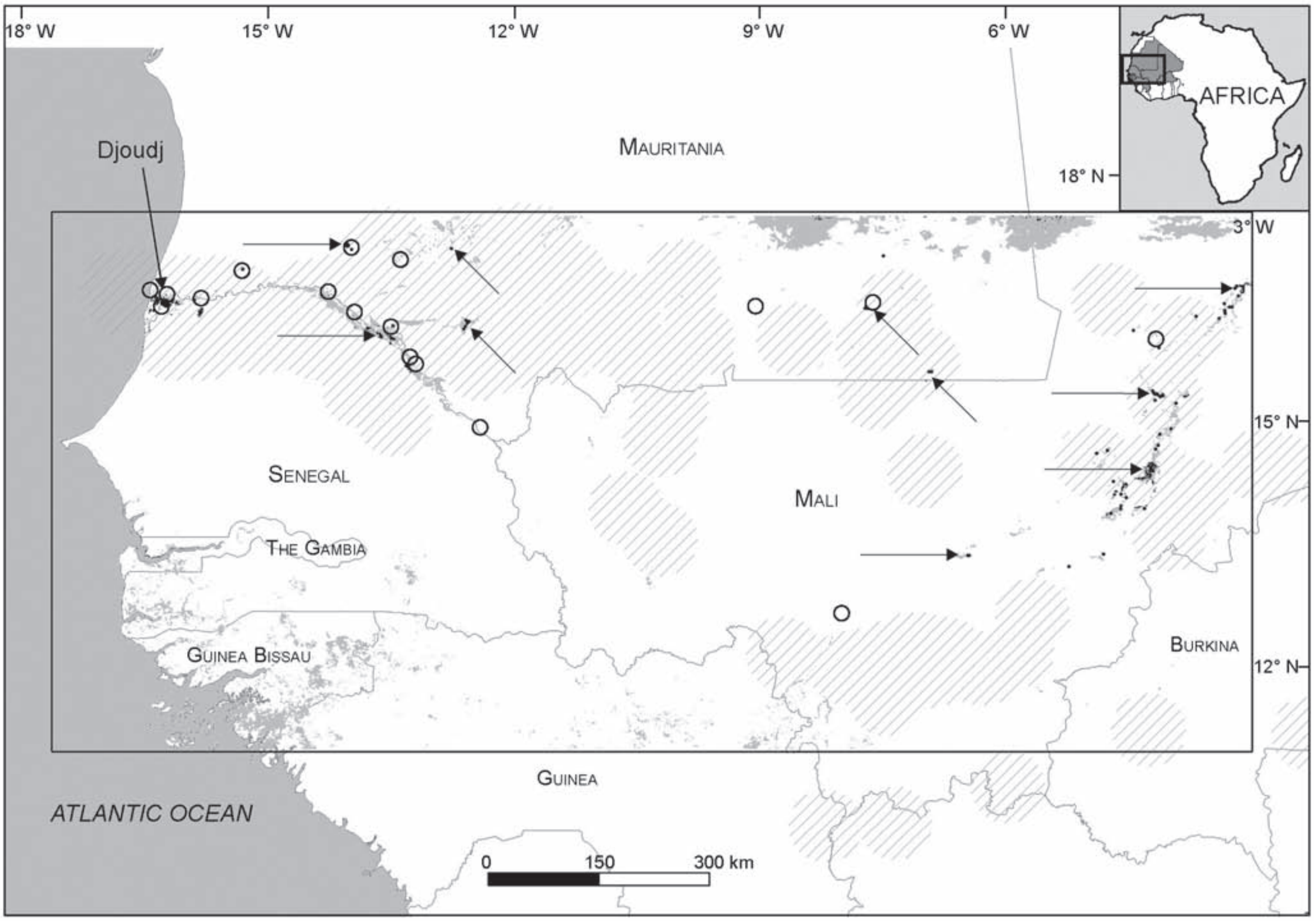
The Inner Niger Delta is of outstanding importance as a breeding area for water birds, and as a wintering area for Palaearctic migrants. It is home to large numbers of birds, including hundreds of thousands of wintering Garganeys, Pintails *Anas acuta* and Ruffs *Calidris pugnax*, and breeding colonies of cormorants, herons, spoonbills, ibises and other waterbirds, including the endangered West-African subspecies of the Black Crowned Crane (*Balearica pavonina pavonina*).

2.10

Recently, the AWCT has also made attempts to find additional African wintering sites using miniature tracking devices (see also **Box 2.9.1** in Chapter 2.9). In summer 2010, 30 Aquatic Warblers from an isolated breeding population in central Ukraine (Supii) were equipped with light-level geolocators as part of a joint project with the Swiss Ornithological Institute. In the spring of 2011, three functional geolocators were recovered. One of the birds was found to stage in Africa, far south of the known wintering areas, although this could be caused by high variance, which increases with shorter distances to the equinox. Nevertheless, this result, together with a record from northern Ghana (Hedenström et al. 1990), could point to a wintering site in that region (Salewski et al. 2013). Another study in summer 2012, in which 47 geolocators were fitted to Aquatic Warblers in central Ukraine (Supii) and western Belarus (Dzikoje), with data retrieved from seven devices the following spring, pointed to winter staging sites mainly in western Mali and the Inner Niger Delta, and in the north of Ivory Coast (one bird; Salewski et al. submitted, see **Fig. 2.10.14**). None of these birds visited Djoudj, all the birds having crossed the Sahara further east from Djoudj and the Atlantic coast.

From these findings, we can conclude that, in accordance with the results from the stable isotope analyses, the mist-netting and ringing activities, and the bioclim modelling (see above), the wintering range of the Aquatic Warbler encompasses the whole of the western Sahel region between Djoudj and the Inner Niger Delta in Mali, including smaller Sahelian wetlands in western Mali and southern Mauritania (**Fig. 2.10.15**). Some birds might also spend the winter further south, as far as northern Ivory Coast (one geolocator bird) and Ghana (two records at Lake Tono). Taking into account that none of the geolocator birds from central Ukraine and Belarus stayed in Djoudj for a longer time, and the birds mostly migrated some distance to the Atlantic coast; and considering the ringing recoveries documenting connectivity between central Ukraine and the Inner Niger Delta in Mali on the one hand, and Biebrza and Djoudj on the other hand, we can assume that Djoudj is mainly used by the westernmost populations (Poland, probably also Lithuania), whereas Mali hosts the Belarusian and Ukrainian populations in winter. This hypothesis would be worthwhile proving and confirming through another geolocator study, which is planned for 2018/2019.

▼ **Fig. 2.10.12**
A wet depression with the highest density of Aquatic Warblers observed in the Inner Niger Delta in February 2011 (photo: J. Foucher).

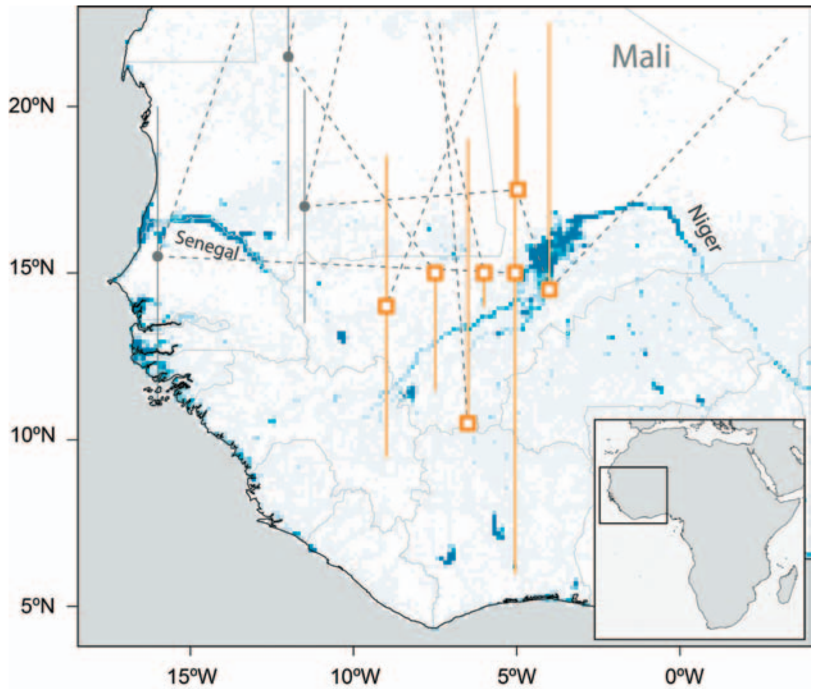


▲ **Fig. 2.10.13**

Distribution of potentially suitable Aquatic Warbler wintering areas based on the analysis of satellite images and stable isotope research. Areas predicted by one of the remote sensing models used are light grey and those predicted by both models are black. Hatching denotes areas identified according to stable isotopes concentration in Aquatic Warbler feathers from the breeding sites. Circles mark location of historical records. The Inner Niger Delta is the most promising search site for the near future (from Buchanan et. al. 2011, copyright © NISC (Pty) Ltd, reprinted by permission of Taylor & Francis Ltd, http://www.tandfonline.com on behalf of NISC (Pty) Ltd)**.**

► **Fig. 2.10.14**

Winter staging records, as revealed by the results of geolocator research (Salewski et al. submitted)**.**



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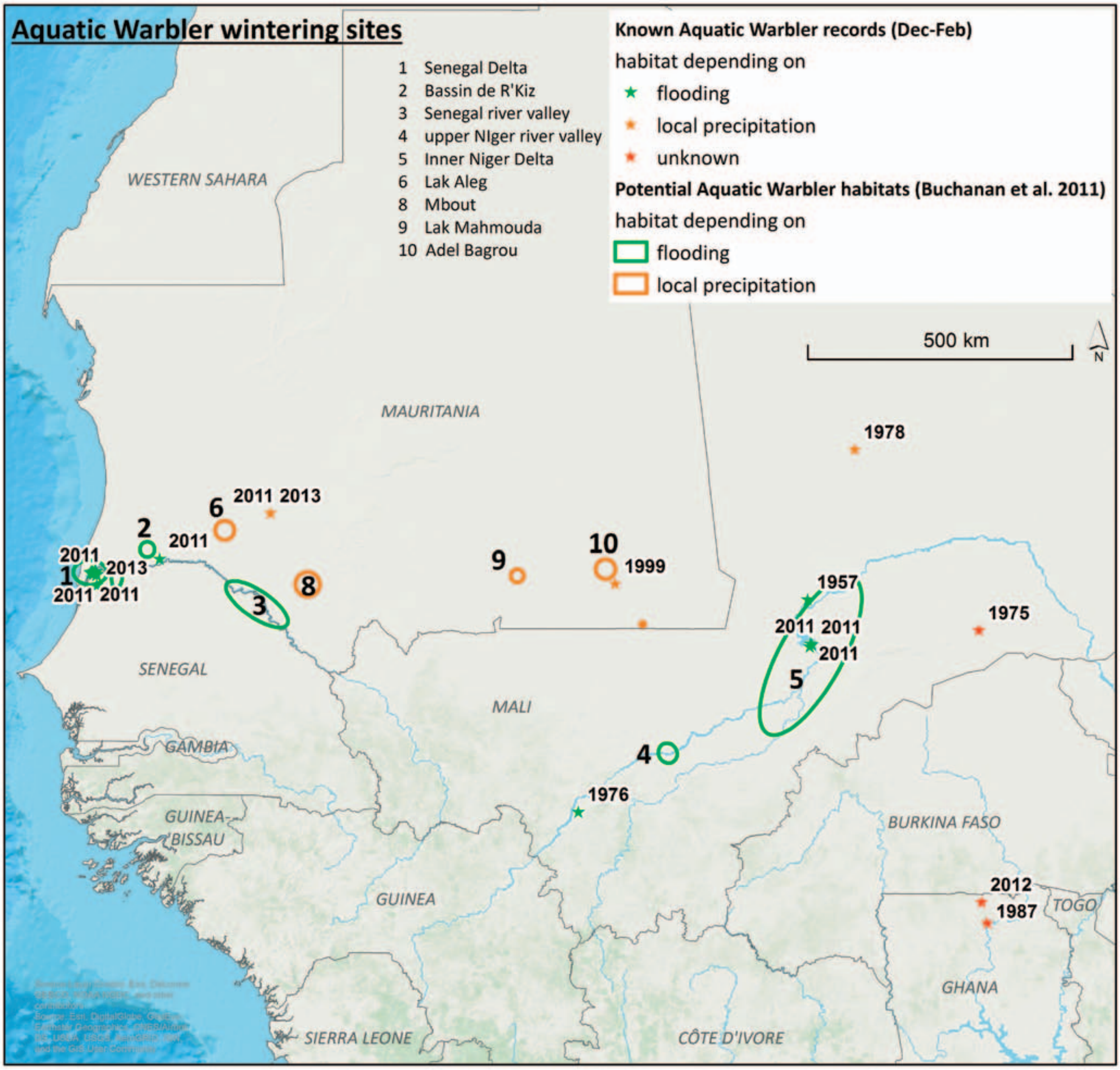

▲ **Fig. 2.10.15**
The known Aquatic Warbler records in the wintering quarters (map by C. Tegetmeyer).

Threats

Concern is growing that the availability of suitable sites is limited and decreasing. Although the Djoudj site itself is well protected, it is affected by changes in salinity, grazing, and the spread of Southern Cattail (*Typha domingensis*), for example. The main threats to natural Sub-Saharan wetlands that form Aquatic Warbler habitats are evident in the vicinity of the Park, which is surrounded by rice fields and freshwater reservoirs. The expansion of irrigation agriculture (mainly rice and sugar cane) in Senegal and other West-African countries particularly affects wetland areas, because here the water supply for fields is granted. Land reclamation is currently developing rapidly due to population growth, increasing purchasing power and the government's strong aim to achieve self-sufficiency in food production. Furthermore, the growth in agriculture is destroying huge areas of grazing land, placing additional pressure on remaining wetland habitats through increased grazing intensity. Additionally, large areas of formerly (probably) suitable habitat within the putative wintering range in northern Senegal and southern Mauritania have been recently lost through transformation into fresh water reservoirs (e.g. the Diama Reservoir at the Lower Senegal River, and Keur Macène in Mauritania) or into irrigated hydroagri-cultural crops (rice, sugar cane; e.g. south of Richard-Toll in Senegal).

Building large up-river dams on the Niger River is likely to affect the presumed second important wintering area, the Inner Niger Delta (Zwarts et al. 2009, Zwarts 2010). Its inundation is highly dependent on the inflow from the Niger and the Bani rivers, where three dams are operational. The Markala Dam on the Niger was constructed by the French colonial authorities between 1934 and 1945 to irrigate farmland for cotton production. Today, the irrigation system is managed by the Office du Niger for rice crops. The Sélingué Dam started operation in 1982 and has been used for the generation of hydroelectric power, irrigation, and fishing. The Talo Dam was built in 2005 for the irrigation of crops and to create fish ponds. The construction of two more dams upstream of the Delta has been considered recently: Fomi, to provide hydroelectric power, irrigation and flood control, and Djenné. The Office du Niger is also planning an extension of the irrigation system. In a relatively dry year, the existing infrastructure leads to a reduction in the inflow to the Delta by 16%, of the flood extent by 1,400 km^2 (13%), and of water depth by 28 cm. The construction of the Fomi and Djenné dams, and the expansion of the Office du Niger irrigation system would cause an additional reduction of the flood extent by 2,700-3,500 km^2, meaning that 56% of the Inner Niger Delta floodplains could be lost due to the construction of hydrological infrastructure (Zwarts 2010). This might be further deteriorated by lowered rainfall, the amount of which has been decreasing in the Inner Niger Delta since the 1960s. It is uncertain whether the decline will continue, but models suggest it is likely. The effect of dams is more intense in dry years, as the same amount of water is used by the infrastructure, and less water is discharged downstream to feed the Delta. Hence, a combined effect of a dry year and dams could be disastrous to the wetlands of the Inner Niger Delta (Zwarts 2010).

In general, threats affecting Sub-Saharan wetlands are: drying up due to periods of drought, overgrazing of grasslands by cattle, the succession of grass associations into scrub, increasing desertification due to climate change, salinisation of irrigated soils, and the construction of new dam structures. Therefore, drought and habitat alteration in the winter quarters are likely to be or become additional bottlenecks for the Aquatic Warbler.

The main activity for the protection of the Aquatic Warbler in Sub-Saharan West-Africa has to be the identification and preservation of key wetlands used by the species, which is still possible, depending on political will. In the long term, it is necessary to develop a high acceptance within the population, based on such factors as poverty reduction and the reintroduction of sustainable agriculture.

3 Threats and limiting factors

3

Threats and limiting factors

FRANZISKA TANNEBERGER, ALEXANDER KOZULIN, ANATOLII POLUDA, JOCHEN BELLEBAUM, LARS LACHMANN & MARTIN FLADE

This chapter summarises threats and limiting factors in the breeding sites. The order of sections reflects a hierarchy: most importantly, habitat condition and especially site hydrology need to be addressed. Also eutrophication and abandonment of low-intensity land use are severe threats that determine habitat quality and management needs (see also Chapter 4.1). On the long-term, Aquatic Warblers at key breeding sites such as Zvaniec and Sporava seem to slowly decline because of habitat loss caused by succession. Whereas in the EU, mowing funded by agri-environmental schemes (Chapter 5) can counteract such habitat loss to some extent, especially outside the EU the restoration of near-natural water regime and water quality and the development of sustainable funding mechanisms are crucial. Additionally, fluctuations of Aquatic Warbler numbers seem to be caused by water level fluctuations during breeding season, such as prolonged flooding (2005, 2009, 2010) and drought (2001,2015). Infrastructure is a threat in some breeding sites. Climate change may also affect Aquatic Warbler breeding populations, but less directly.

The population trend of a species mainly depends on its breeding productivity and the survival rate of fledged young and adult birds throughout the year. While the first factor is mainly influenced by the conditions at the breeding sites (see below), the second factor is – for a long-distance migrant, such as the Aquatic Warbler – mainly determined by the existence and quality of suitable stopover and wintering habitats. They are described in Chapters 2.9 and 2.10, and threats present at these sites are not treated in detail here. Thereby it should also be remembered that it is possible to maintain a population as stable, even if one of the two contributing factors is deteriorating, if at the same time the other factor improves. This means that e.g. decreased adult survival through the loss of suitable wintering habitat to some extent could be compensated through higher breeding productivity at improved breeding habitats.

Overall, sound knowledge of Aquatic Warbler ecology, especially population dynamics and habitat conditions, is essential for understanding threats and limiting factors. And knowledge on habitat management effects (see Chapters 4.1-4.6) is crucial for addressing these threats properly. The main recommended research and monitoring activities are summarised in Chapter 6.

Habitat destruction for agriculture or other land use

This threat is responsible for the dramatic historical decline of the species (Chapter 2.2; AWCT 1999, BirdLife International 2015). Europe is the continent with the largest proportional mire losses because of its long history of high human population pressure and climatic suitability for agriculture. As peat extraction, subsidence, oxidation, and erosion following human activities have changed many former peatlands into mineral soils, some 10% of the maximal peatland area during the Holocene (c. 650,000 km^2) does not exist anymore as peatlands. Out of the remaining 594,018 km^2 of peatland in Europe, 286,550 km^2 are degraded (Joosten & Tanneberger 2017). Open fen mires were and are particularly threatened because of their susceptibility to disturbance of the groundwater level, their suitability to convert them to grassland, and – in the case of fen mires in river valleys – easier accessibility compared to raised bogs.

Agriculture has been and still is the principal cause of mire loss: over the whole of Europe, drainage was mainly for agriculture (50%), forestry (30%), and peat extraction (10%; Joosten & Clarke 2002). Starting from the 8th century, the extensive mires of Holland were colonised and used as meadow, pasture, or arable land. As early as in 1100 the technique of peatland reclamation and colonisation had achieved such a success that the Dutch expertise was exported to Germany (Borger 1992), and soon later beyond towards the East (**Fig. 3.1**). Overall, in the Netherlands (a country with former Aquatic Warbler breeding records) not one fen has stayed untouched, no square meter of mire has been saved from draining, cutting, burning, farming, or building (**Table 3.1**).

In central Europe, peatlands have been used for agriculture at least since the 13th century (Zeitz 2016) and peatland drainage is documented from the early 17th century onwards. In Brandenburg, a former stronghold of the species, the previously shallow lowering of water tables changed into intensive drainage from the mid-18th century onwards. After more than 150 years of continued drainage and cultivation of fens, Hesse (1910, 1911, 1912) still witnesses large wet sedge fens around Berlin with impressive diversity and abundance of breeding birds, including the Aquatic Warbler (see the quote in Chapter 2.1). He also describes the conversion of slightly drained fens into deeply drained fens in this area: 'The 'former' birds of the 'former' fen mires, I should say when talking about the true fen mire. Unfortunately, even the vast marshes, the fens of the Havel lowland, where until recently an incomparable richness of birds bred, fell victim to sateless culture; because of the large drainage

▼ **Fig. 3.1**
Export of Dutch peatland reclamation expertise to the surrounding countries (from Tanneberger et al. 2017, after Danner et al. 2005).

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▼ **Table 3.1**

Total current (drained and undrained) peatland area, total current mire (= undrained peatland where peat is being formed) area, and estimate of mire loss for Aquatic Warbler breeding range countries (after Tanneberger et al. 2017b). Data refer to areas with a minimum peat thickness of 30 cm. The figure for mire loss is a conservative estimate, as those areas of the original mire area where the peat layer had disappeared completely are not included. * includes substantial areas of restored peatlands.

Country	Total current peatland area (km²)	Total current mire area (km²)	Estimate of mire loss (%)
Austria	1,200	175	>85.4
Belarus	25,605	8,630	>66.3
European Russia	235,000	150,000	>36.2
Germany	12,800	250*	>98.1
Hungary	300	75	>75.0
Latvia	7,514	3,165	>57.9
Lithuania	6,460	1,781	>72.4
Netherlands	2,733	150*	>94.5
Poland	14,950	2,390	>84.0
Ukraine	10,000	6,395	>36.1

works of recent years, these fens will be destroyed for ever, and many of them are already. And of all the vanished glory, only the bitter word remains: It is over.' (Hesse 1914, translation by F. Tanneberger). From the early 20th century, large areas of (shallow) peatlands were deeply ploughed. In some peatlands the so-called 'Sanddeckkultur' was established (i.e. the peat layer was covered with a mineral layer, Göttlich & Kuntze 1990). The 'Komplexmelioration' applied in East-Germany from the 1960s until the 1980s standardised ditch distances, depths, and slope gradients, and merged smaller drained fields to extensive coherent fields suited to large machinery (**Fig. 3.2**). Aquatic Warbler habitats in Germany were destroyed completely after World War II, increasingly from west to east. In Brandenburg, the Aquatic Warbler had disappeared from most fen areas by the 1970s (Heise 1970b, Wawrzyniak & Sohns 1977) and only one (easternmost) site remained occupied until the 21st century. Overall, 98% of peatlands in Germany were drained (**Table 3.1**). In Austria (where the Aquatic Warbler formerly bred) more than 85% of the mire area has been drained, and only some 600 ha of the formerly much larger percolation mire area remained undisturbed (Essl & Steiner 2017).

In Poland, large-scale reclamation of fens for agriculture started in the 18th century, but the most intensive drainage works occurred during the period of the People's Republic of Poland (1952-1989), leading to the drainage of the large majority of mires (**Table 3.1**). In contrast to other European countries, however, only a few peatland areas have been transformed into arable fields. The national management principles recommended the use of peatlands as permanent grassland to minimise the loss of organic matter through mineralisation (Kotowski et al. 2017). Some of the largest drainage campaigns of fen mires took place in the 1960s, with the drainage of Bagno Wizna just south of the Biebrza National Park being the most famous example.

In Hungary, in the 17th-18th century traditional peatland use changed and the conversion of peatlands (most of them being fens) into cultivated land began. By the end of the 20th century, the majority of the Hungarian mires had been drained for grassland or arable land. Important peatlands have been converted into maize cultures, using huge state subsidies (Szurdoki et al. 2017).

▼ **Fig. 3.2**

(left) Peatland cultivation by deep ploughing in the Rhinluch, Germany, 1988 (photo: M. Succow).

▼ **Fig. 3.3**

(right) Industrial milled peat extraction in Tsna, Minsk oblast, Belarus, 2014 (photo: H. Joosten).

In eastern Europe and the Russian Federation (i.e. former Soviet Union countries), the first drainage activities were carried out in the 16th century (on the territory of modern Belarus; Bambalov et al. 2017). Agricultural use of peatlands was studied and promoted by Czar Peter the Great in the early 18th century. In the second half of the 18th century, Mateusz Butrymowicz initiated the first large-scale drainage activities in the Polesie region. The large-scale conversion of peatlands to arable land and meadows started in the 1880s/1890s with two well-known state expeditions (the 'Western Expedition' headed by General Iosif Ippolitovich Zhilinskiy and the 'Northern Expedition' headed by Ivan Konstantinovich Avgustinovich). These expeditions aimed at promoting economic development of highly paludified and 'unhealthy' areas. After 25 years of work, 2.5 million ha had been drained and 4,657 km of channels, 549 bridges, and 30 sluices built by the 'Western Expedition'. Another 100,000 ha of land were drained by the 'Northern Expedition' in 1877-1899 (Bambalov et al. 2017). However, vast parts of the large continuous mire areas of Polesie in Belarus and Ukraine were intensively drained only in the 1970s and 1980s (Bambalov et al. 2017).

In Belarus, the original extent of mires before drainage and peat extraction was at least 2,560,500 ha. Only 4.5% were raised bogs; most mires were fens or transitional mires. Before drainage, c. 70% of the fens were open (Kozulin et al. 2017). The current extent of mires is 863,000 ha, distributed across 1,348 sites (**Table 3.1**, **Fig. 3.4**). This also includes peatlands that have been slightly drained for forestry. Some 946,000 ha of mires were drained for agriculture and 299,100 ha were drained for peat extraction (**Fig. 3.3**; Bambalov et al. 2017). Large-scale drainage of fen mires continued until the mid-1990s, even in the core breeding sites of the Aquatic Warbler (Zvaniec, Sporava; see **Box 3.1**).

In Ukraine, drainage of mires began in the late 19th century, especially in 1873-1898 in the Volyn, Rivne, and Zhytomyr oblasts, where more than 4,700 km of drainage channels were constructed. The drained land was converted into pastures and hay meadows. A further 5,265 km of drainage channels were constructed in 1909-1914 and by 1917 c. 430,000 ha of mires had been drained, with the land used as pastures. After 1917, the drainage rate varied, but the total area of drained land increased. After World War II, there was an increase in drainage of mires in northern Ukraine. Around 1980, the total area of drained mires totalled 613,900 ha, i.e. c. 50% of the original mire area (Movchan

Box 3.1

Habitat 'discovery' and loss in Belarus

MARTIN FLADE & ALEXANDER KOZULIN

Before 1995, it was assumed that the Aquatic Warbler was extinct in Belarus. Thanks to a meeting between Martin Flade, interested in the species after having joined fieldwork of Andrzej Dyrcz and Karl Schulze-Hagen in the Biebrza Marshes in 1990, and Alexey Tishechkin at the BirdLife International Corncrake workshop in Gdańsk in 1994, a joint German-Belarusian expedition in search of Aquatic Warblers in Belarus was organised by Alexander Kozulin. The expedition took place in May 1995 and substantial numbers of Aquatic Warblers were found near Pinsk and in Zvaniec. It became clear that Belarusians had – despite of their excellent knowledge of their landscape and nature – simply omitted this species while being focused on other target species, mainly water birds, raptors, and waders. At the time of this 'discovery', drainage and land reclamation was still ongoing at several fens, e.g. in the Zvaniec Mire (**Fig. 3.5** and **3.6**). Severe drainage of this big fen mire started only in 1987, and large areas in the northern and southern part were drained between 1987 and 1993. Understanding the global importance of Belarusian undrained fen mires catalysed conservation activities, such as the designation of reserves and management planning in Belarus.

From aerial images of open fen mire areas since the 1960s, Kozulin & Flade (1999) estimate that the suitable habitat area and population size of the Aquatic Warbler must have suffered a decline of more than 90% within the last 30 years, mainly due to drainage, land reclamation, and peat extraction. As indicated by old topographical maps, vegetation maps, and information given by the state drainage and land reclamation institutes of Belarus (Belmeliovodhoz and Belgiprovodhoz), nearly 15,000 km² of fen mires have been drained since 1960. The currently known breeding habitats were identified on a high-quality vegetation map of Belarus from 1977 (Yurkevich et al. 1979), scale 1:750,000, and could be associated precisely with two vegetation units (41a and 41b), which still covered c. 3,800 km² on this map. These vegetation types decreased to c. 440 km² in 1995-1998, out of which c. 154 km² (15,400 ha) are thought to be still suitable for the Aquatic Warbler.

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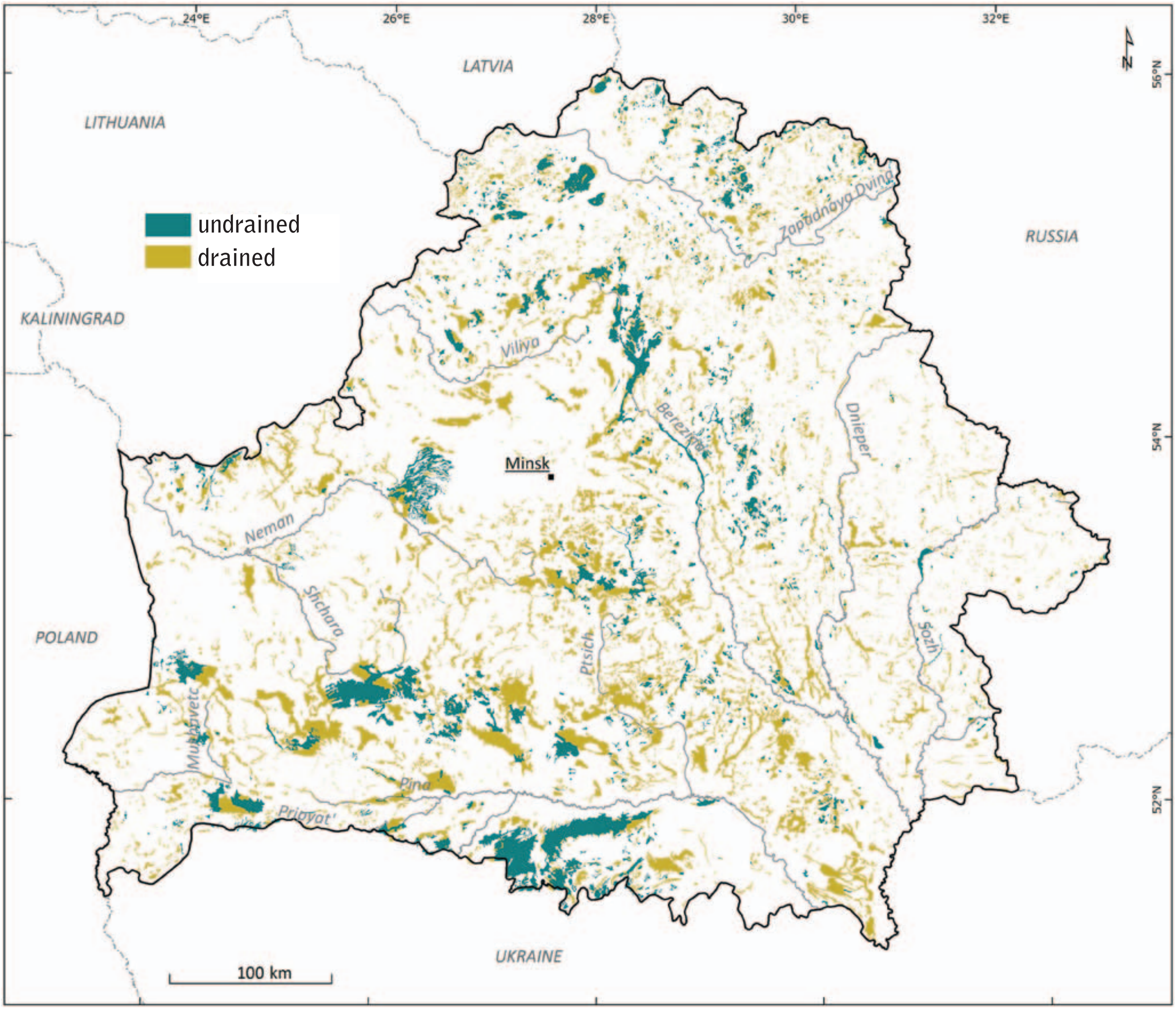
et al. 2017), and the overall area of drained wetlands in Polesie was c. 1.6 million ha (Kozlovskyi 2005, Zuzuk et al. 2012). Most mires were drained for agriculture (in total c. 365,000 ha during Soviet times, especially in Polesie; Movchan et al. 2017).

In Latvia, the most intensive drainage projects were conducted in 1960-1980. Drainage has affected c. 434,900 ha of the original mire area. Some 50% of the Latvian peatland area is classified as fen, and in particular fens have been converted on a large-scale into drained agricultural land (Pakalne & Aleksāns 2017). In Lithuania, intensive land drainage for agriculture commenced in the early phase of the Soviet period. At present, c. 468,000 ha of peatlands have been drained for agriculture or forestry. Land drainage mostly affects fens (78% of the total fen area drained) and transitional peatlands (58%), while bogs are less affected (41%; Povilaitis et al. 2011).

The rate of active destruction of breeding sites through drainage and conversion for agriculture, forestry, or peat extraction has slowed considerably in the past 15 years, so that this threat is now localised, but critical where it occurs. In Ukraine, the government stimulates the extraction of peat. In 2017 new extraction sites were drained and prepared for peat extraction near the village of Karasin (Volyn region) close to Aquatic Warbler breeding sites (Fig. 3.7).

▼ **Fig. 3.4**
Current peatland distribution and drainage status in Belarus based on Scientific and Practical Centre for Bioresources 2016; only peatlands >10 ha are depicted (after Bambalov et al. 2017).



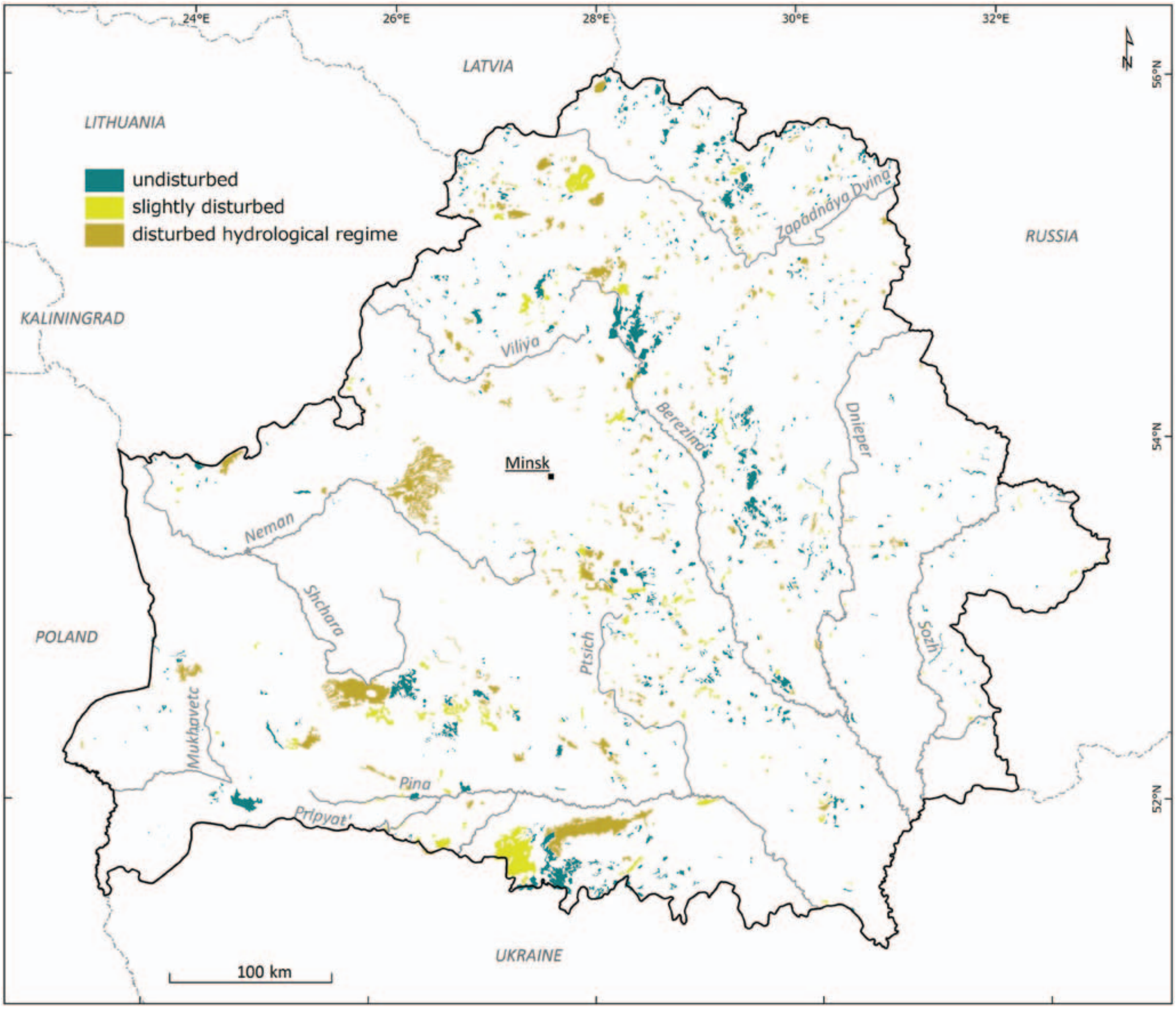
▲ **Fig. 3.5**
(left) Peatland destruction in Zvaniec, Belarus, May 1995 (photo: M. Flade).

▲ **Fig. 3.6**
(right) Digging of drainage ditches in Zvaniec, Belarus, May 1995 (photo: M. Flade).

◄ **Fig. 3.7**
Drainage and preparation for peat extraction near Karasin (Volyn region) close to Aquatic Warbler breeding sites, Ukraine, March 2017 (photo: M. Khymyn).

Alteration of the hydrological regime

Most Aquatic Warbler sites suffer to various degrees from anthropogenic changes in the hydrological regime. The disturbance of the natural hydrological regime as a result of drainage and hydro-technical construction leads to the degradation of mires accompanied by overgrowing of open areas by forests, shrubs and Reed, increased eutrophication, and drying up of small water bodies, rivers, and streams. This can lead to (1) lack of water during spring and summer, causing unsuitable Aquatic Warbler habitat conditions,(2) vegetation succession to more shrubs and moist meadow vegetation, and resulting loss of Aquatic Warbler habitat, and/or (3) summer flooding with destruction of Aquatic Warbler nests (e.g. Vergeichik & Kozulin 2006a, Kubacka et al. 2014). For example, in Belarus a substantial part of the remaining mire area has a slightly or severely disturbed hydrological regime (Kozulin et al. 2012; **Fig. 3.8**). Low -intensity mowing can compensate for the effects of moderate drainage and maintain suitable habitats, as it has happened in many key breeding sites for long periods (e.g. Biebrza, Zvaniec, Sporava, probably also Rhinluch, Havelländisches Luch, Rietzer



▲ **Fig. 3.8** **Hydrological disturbance of Belarusian mires** (after Kozulin et al. 2012, from Bambalov et al. 2017).

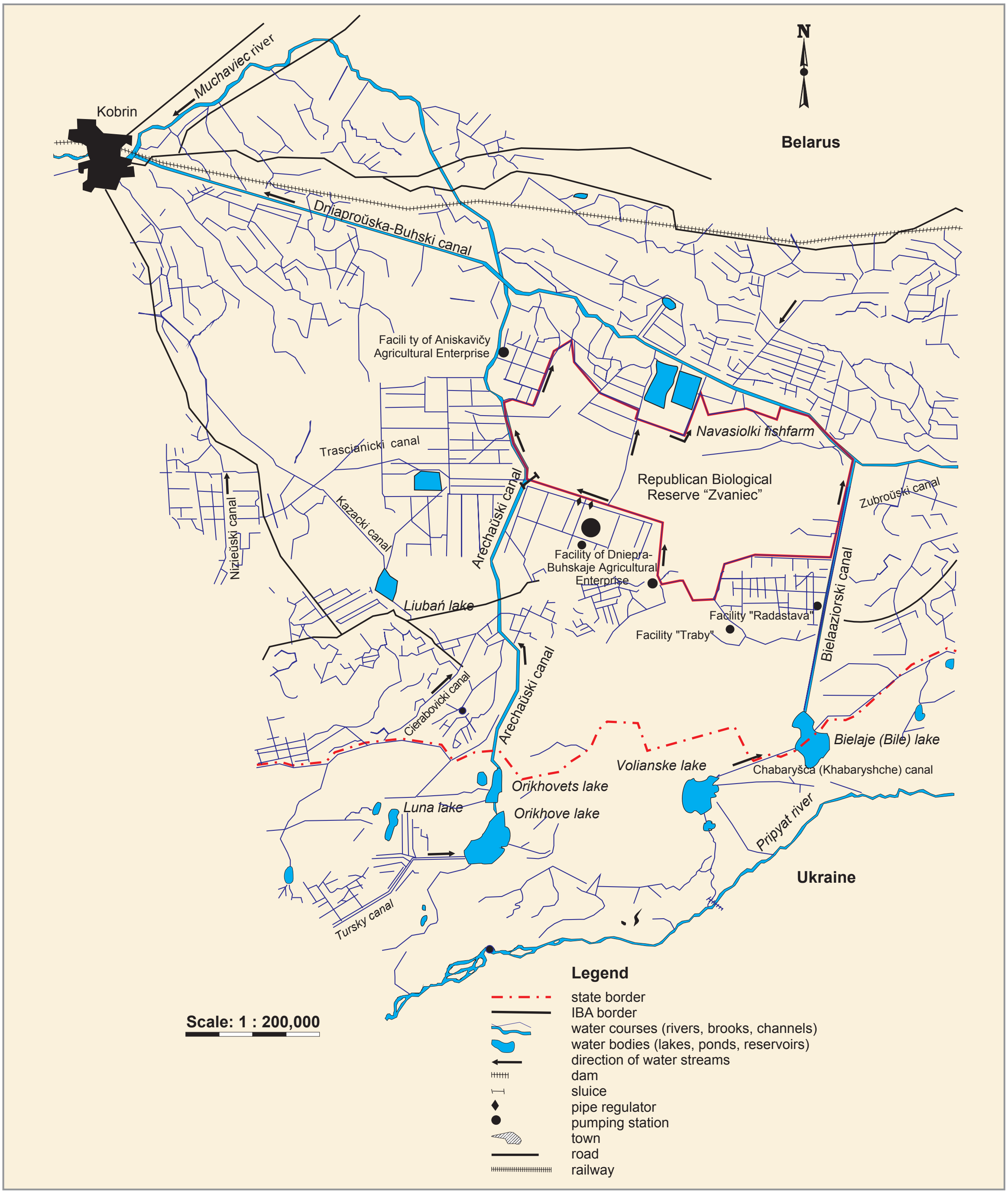
See, and other German sites; see also below and Chapter 4.4). Thus, moderate drainage does not destroy habitats completely, but leads to increased land use dependency of a site as Aquatic Warbler habitat (see Chapter 4.1).

In many cases, remaining Aquatic Warbler breeding sites are not directly affected by melioration infrastructure, but indirectly negatively influenced by surrounding areas with an altered hydrological regime. Currently there are problems at several sites in Ukraine (e.g. Upper Prypiat), Belarus (e.g. Zvaniec, Dzikoje, Sporava), and Poland (e.g. Ner Valley) with drainage and peat extraction affecting adjacent sedge fens. The Zvaniec Mire in southern Belarus, the world's largest breeding site of the Aquatic Warbler, illustrates this threat particularly well: the remaining fen mire is surrounded by dense drainage networks at all sides (**Fig. 3.9**) and has a severely disturbed hydrological regime.

Also river regulation, such as river bed deepening, canalisation of rivers, and damming of floodplains alter the hydrological regime of fens inhabited by the Aquatic Warbler. The last prominent case of an Aquatic Warbler site in Poland being affected by river bed deepening was at the Ner river around the year 2006 near the border of Wielkopolskie and Łódzkie voivodeships. River bed deepening as a threat for Aquatic Warbler habitats is in particular evident at the upper Prypiat river in Ukraine (**Fig. 3.10**). Here, direct destruction of fen mires in the floodplain stopped in the late 1980s/early 1990s. But deepening of the river bed continues. In 2004-2007 such works were carried out on 13 km length of the Richytsia-Pidhiria-Turiia-mouth floodplain section. In 2006, the river bed in a 1.5 km section downstream of the Vetly village was deepened, affecting the Aquatic Warbler breeding sites Vetly-Birky-Tsyr and Vetly-Hirky-Liubotyn. In 2007, the water level in the nearby Aquatic Warbler monitoring plot was the lowest since 1995, and Aquatic Warbler number of the Prypiat population was 300-400 singing males (s.m.) lower than in the two previous years (Poluda 2008). Recovery of the river bed after dredging is rather slow, e.g. in the Pidhiria-Turiia mouth, where large amounts of water discharge through the deepened river bed draining the floodplain.

During the 2017 survey of the breeding sites of the Desna-Dnipro population, hydro-

Fig. 3.9 **Map of Zvaniec and its surroundings showing the melioration infrastructure all around and the mire as an 'island' in the middle** (after Schäffer et al. 2002a).



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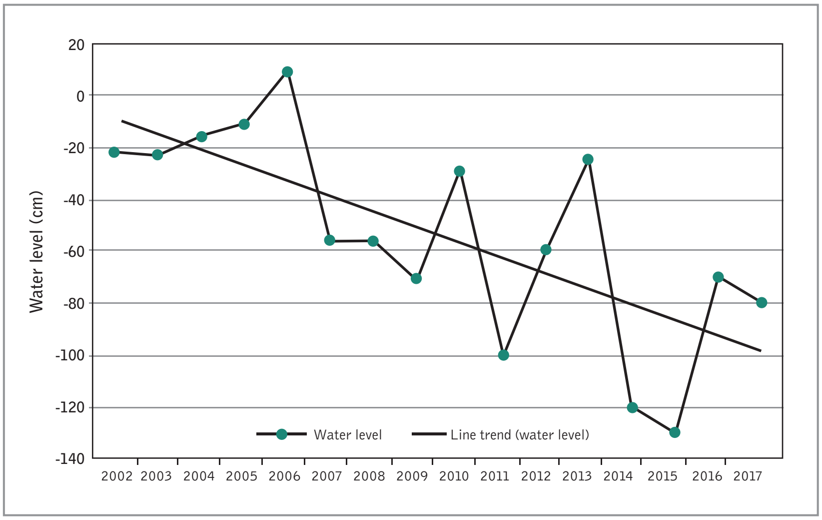

▲ **Fig. 3.10**
River bed deepening in Prypiat river floodplain, Ukraine, 2007 (photo: A. Poluda).

▲ **Fig. 3.11**
Dynamics of water level in the floodplain of the Udai river on the border of the Chernihiv and the Poltava regions in the period 2002-2017 (beginning of June).

logical conditions were not optimal in the majority of sites: due to sluices and dams, three important breeding sites were completely dry, and optimal conditions were observed only in one site. In the floodplain of the Udai river on the border of the Chernihiv and the Poltava regions, water levels have been recorded since 2002, and there is a clear overall drop in water levels (**Fig. 3.11**; Poluda 2017).

Recently, a new transnational initiative E40 aimed at establishment of a 3,000 km Black-to-Baltic Sea waterway through territories of Poland, Belarus, and Ukraine accommodating all year navigation of sea-to-river boats is under development. The planned construction works would include deepening, straightening, damming and flood prevention at the Prypiat river and are likely to affect several protected areas, including at least four Aquatic Warbler breeding sites.

Even slight changes of the hydrological regime may have an impact on the natural rate of successional overgrowth with trees and bushes. While natural fen mire sites might grow over within several thousand years, while at other sites new mires develop, this equilibrium does not work anymore for sites with changed hydrology, which might completely grow over in as little as 50 years or less depending on the size of the site. Once shrubs or trees are established, they themselves alter the hydrological conditions through increased evapotranspiration, thus lowering the water table.

Eutrophication

Nutrient levels have a significant effect on fen vegetation, biodiversity, and nature conservation value. Understanding how and why nutrient regimes are subject to change, and the problems which can arise as a result, is therefore critical to fen management. Nitrogen (N), phosphorus (P) and potassium (K), collectively referred to as plant macronutrients, are the most significant agents of enrichment as they are the major plant nutrients that typically limit plant growth in a fen (McBride et al. 2010). In fens and wet grasslands, P limitation of plants is widespread, which implies that the conservation of endangered species requires the restoration and conservation of P-limited ecosystems (Wassen et al. 2005).

A major threat to fens and fen biodiversity is eutrophication – an increase in nutrient input into the system by human land management activities. Sources of nutrient input into fens include groundwater inputs, surface water inputs or atmospheric inputs, through point sources, diffuse sources, and internal nutrient enrichment (McBride et al. 2010). Typical sources of eutrophication of fen mires include:

- intensive agriculture with fertiliser application within the water catchment areas of the fen;
- drainage of organic soils and resulting peat decomposition;

- pollution of river waters by industrial and sewage waters;
- airborne nutrient deposition.

Originally, Aquatic Warblers probably found their natural habitat in low productive fen mires (see Chapter 2.3). Increasing drainage and eutrophication accelerates vegetation succession to taller and denser vegetation, possibly with less potential food, and thus to conditions less suitable as Aquatic Warbler habitat. However, such negative changes in the vegetation structure do not manifest themselves if the site is subject to regular land use. Therefore, if increased eutrophication does not immediately lead to a decrease of habitat suitability, it leads at least to an increased land use dependency of the site as Aquatic Warbler habitat (see Chapter 4.1).

Nutrient levels generally decrease along a west-east axis across the Aquatic Warbler breeding range (e.g. levels of atmospheric nitrogen deposition ranged from >20 kg N per ha and year in Germany to 5-10 kg in Poland and <5 kg in Siberia; Holland et al. 1999). In the EU, eutrophication because of excess atmospheric nitrogen deposition has decreased since 2000. But even in a scenario assuming that current legislation is fully implemented, it will, nevertheless, fall short of the 2020 objective of reducing areas of critical load exceedance with respect to eutrophication by 43% from 2000 levels (EEA 2017a). The threat of increasing eutrophication is particularly important in eastern European countries, where atmospheric deposition was previously relatively low. Alternating land use with early and late mowing (see **Box 4.4.2**), which is currently only necessary in strongly eutrophic, moderately drained sites (e.g. Pomerania/Lower Oder Valley sites, see **Box 3.2**, and Lithuania/Nemunas Delta) may in future also be needed in other Aquatic Warbler breeding sites that are subject to succession to higher and denser vegetation due to drainage and high nutrient loads.

In Ukraine, several cases of pollution of Aquatic Warbler breeding sites by nutrient-rich waters were recorded. For example, the site at Bykiv (Supii Valley)

Box 3.2

Effect of interaction of changes in trophic level and land use patterns on the suitability of Aquatic Warbler habitats of the Pomeranian population

FRANZISKA TANNEBERGER & JOCHEN BELLEBAUM

The Lower Oder Valley National Park is a eutrophic Aquatic Warbler breeding site characterised by wet meadows and pastures with the grasses *Phalaris arundinacea* and *Alopecurus pratensis*, and sedges (mainly *Carex acuta*). Aquatic Warblers were common breeding birds in the Lower Oder Valley in the first half of the 20th century (Robien 1920 and unpublished reports), when mosses and sedges prevailed in the floodplain (Weber 1907). In the years up to 1976, when Aquatic Warbler numbers in the study area were high (30-50 singing males according to incomplete counts), their breeding habitat still contained small and less competitive meadow herbs (Tanneberger et al. 2008), which persisted on drier parts thanks to mowing and grazing, and on wet parts thanks to mowing from July onwards, or sometimes even without land use (Dittberner & Dittberner 1976, G. Schalitz pers. comm.). From 1976 onwards, large-scale early drainage of the polders through pumping and nitrogen fertilisation – partly even from aircrafts – with up to 150-360 kg N/ha (Schalitz et al. 1984) favoured the development of monotonous *Phalaris arundinacea* vegetation and facilitated earlier and more complete mowing. Whereas typical *Phalaris arundinacea* vegetation yield in 1966 still contained 44% sedge biomass, this proportion was only 1% in 1983 (Schalitz et al. 1997). With the ongoing homogenisation of the vegetation, Aquatic Warbler numbers also declined (Tanneberger et al. 2008).

In recent years, the most striking phenomenon in the Lower Oder Valley as well as in other Pomeranian sites (e.g. Rozwarowo Marshes) is the abandonment of sedge-dominated vegetation by Aquatic Warblers since 1990. The area classified as Caricetum gracilis in 1993 was preferred by the birds in 1982 and 1986 (forming roughly half of the breeding habitats), but less so after 1995, and has been almost completely avoided since 2000 (**Fig. 3.12**). At the same time, Aquatic Warblers shifted to other meadows dominated, for example, by Phalaridetum arundinaceae. This change can largely be attributed to changes in land use. The sedge meadows occupied prior to 1995 were usually mown twice each year, which counteracted eutrophication and led to a mosaic of sedges, grasses, and herbs. Since 1992, these meadows were only mown once or completely set aside, which caused succession to denser and taller *Carex acuta* (= *C. gracilis*) stands. The other meadows dominated by grasses such as *Phalaris arundinacea* or, in the case of Rozwarowo, Reed (*Phragmites* australis) continued to be mown with a similar intensity and thus constitute today a more suitable habitat than the largely unmown sedge meadows. Along with the decreasing intensity of mowing, vegetation height increased and cover of the herb layer decreased in the period 1993-2006 on sites with late or no land use, whereas on sites with continued early land use no significant changes could be observed. The effects of abandonment can already be seen during the period of gradually reduced mowing intensity (Tanneberger et al. 2008).

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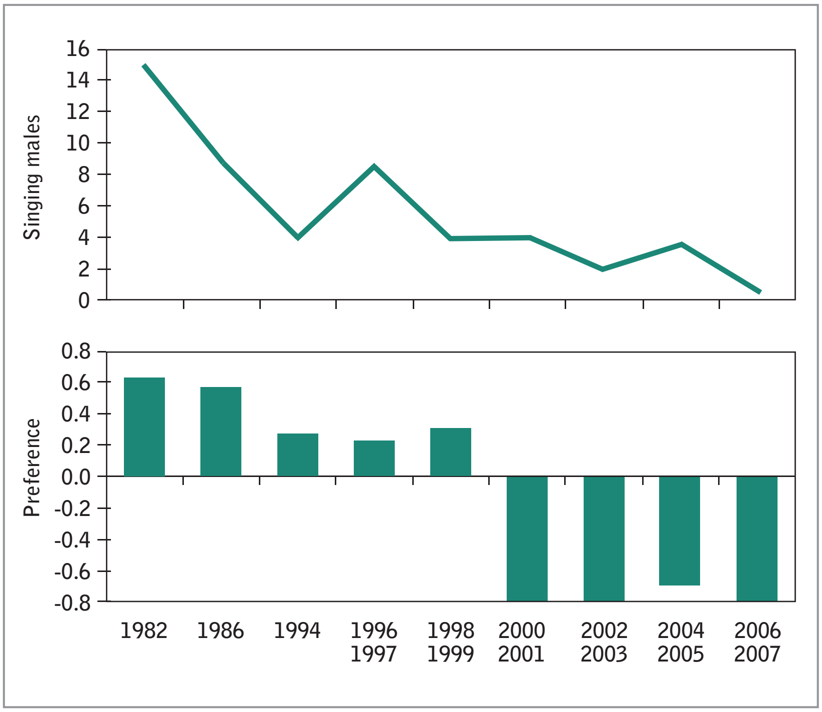


▲ **Fig. 3.12** **Changes in the numbers of Aquatic Warblers (upper panel) and their preference for Caricetum gracilis (lower panel; positive values indicate a preference and negative values an avoidance) in the Lower Oder Valley National Park on the study plots of Jehle & Pankoke (1995). For the period 1996-2005, two-year means are presented. Aquatic Warbler data:** H.-J. Haferland unpublished and J. Sadlik unpublished. Modified after Tanneberger et al. 2010b.

was polluted by the Novobykivskyi sugar factory located a few kilometers upstream in 2005. Vegetation height during breeding season increased from c. 1 m to 1.5-1.8 m, and also vegetation density increased substantially. Aquatic Warbler numbers dropped from 20-25 s.m. in 2005 to zero in 2006-2010. In 2012, the total number was estimated at 15-25 s.m.

Abandonment of land use

Traditional use of undrained or moderately drained fens has played a crucial role in rural economies in many European countries and is still locally practised in countries such as Belarus, Ukraine, and the Russian Federation. Hay-making and grazing have been applied both on wooded mires, which were consequently opened up and changed to open fens, and on naturally open mires, where 100 years of low-intensity land use has changed the hydraulic properties of the peat (Schipper et al. 2007). For a long time, a great majority of Aquatic Warbler habitats in the current range of the species was farmed for hay, which typically consisted in hand-mowing once per year.

At present, virtually all of these sites have been abandoned by farmers. Under such altered conditions as described above, abandonment leads to a change of vegetation and landscape, with increased cover of litter, tall-growing herbs, grasses, and sedges, and expansion of dwarf shrubs, shrubs, and trees (Tanneberger et al. 2017a). Succession is generally faster in southern (warmer) regions than further north, and faster in more nutrient-rich fens (Wheeler et al. 1995). This change in vegetation is called secondary plant succession. In many locations, it is accelerated (or triggered) by factors such as lowered groundwater table (usually caused by drainage works in the neighbourhood) and eutrophication, caused principally by influx of nutrients from surrounding farmland, from air or through peat mineralisation (see above). Secondary plant succession is a threat not only to the Aquatic Warbler but also other species of plants and animals, leading to a decrease in species richness. As succession proceeds, plant species typical of open fen are outcompeted by other species, which are less valuable in conservation terms.

The effects of abandonment can already be seen during the period of gradually reduced mowing intensity. Such successional patterns – an increase of tall sedges and grasses at the expense of small or medium-sized herbs, altogether leading to a decrease in the cover of the herb layer, a reduced overall plant species number, and a thicker litter layer – have been reported in numerous long-term studies of abandoned meadows all over central Europe (e.g. Rosenthal & Müller 1988, Leyer 2002 for floodplain sites including fens, and Jensen & Schrautzer 1999, Falińska 1999, Bakker et al. 2002, Wagner et al. 2003, Güsewell & Le Nédic 2004, Hodgson et al. 2005 for other fens and grasslands).

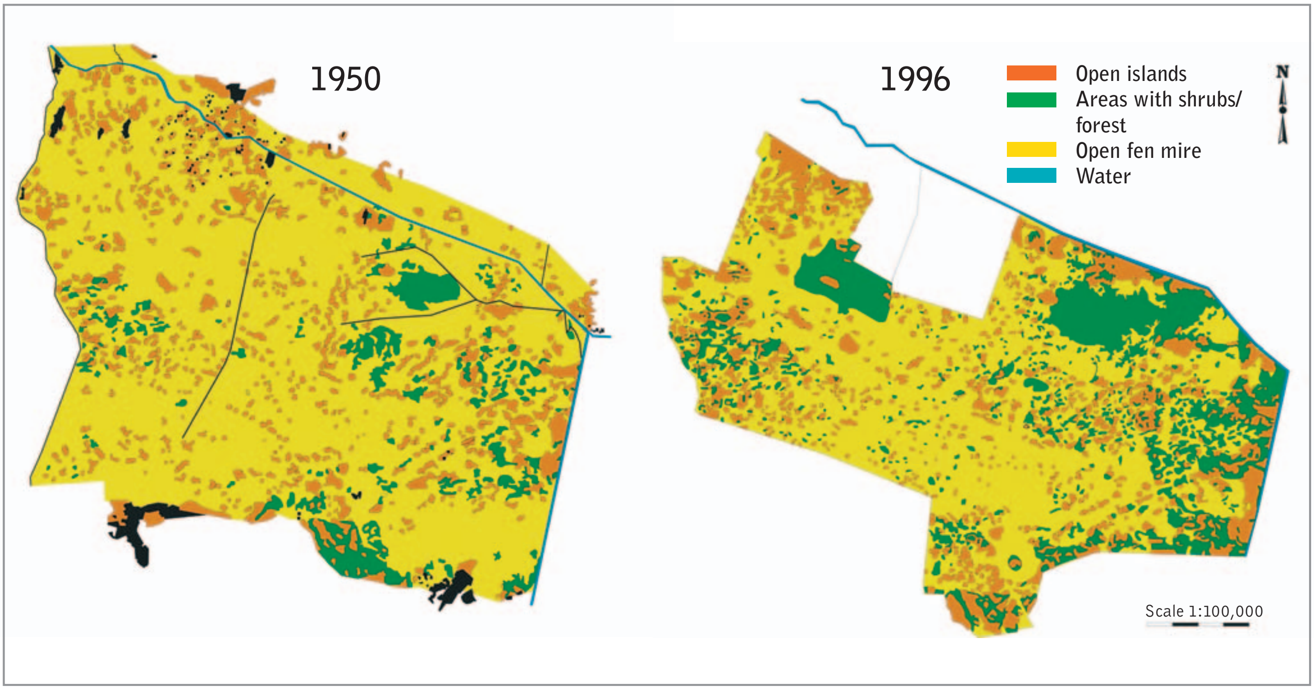
For instance, in the Biebrza National Park in Poland, according to its draft Conservation Plan of 1997, the area gradually overgrown with bushes, trees, and Reed was over 12,000 ha out of the total of c. 40,000 ha of non-forest ecosystems. In addition, to preserve these ecosystems in the Park, it was recommended that on more than 31,000 ha conservation measures or continuation and restoration of low-intensity farming should be implemented (Matuszkiewicz et al. 1999). Suppressing or reversing plant succession in the most valuable non-forest habitats is one of the most vital tasks of the park. Similarly, abandonment and overgrowing was or still is a threat in other Polish breeding sites (**Fig. 3.13**)

In Belarus, overgrowth of sedge fen mires with shrubs and Reed occurs on c. 500,000 ha as a result of hydrological disturbance, eutrophication, and the cessation of traditional forms of land use. Despite the fact that the most important mires are designated as protected areas, the biodiversity of these ecosystems continues to rapidly decrease (Bambalov et al. 2017). Comparative analysis of aerial photos has indicated that the area of open fen mires shrunk due to encroachment with shrubs and trees in all three main breeding sites. In Zvaniec, the area of open sedge fens decreased by 11% in 1950-1996 (**Fig. 3.14-3.16**), in Sporava by 20%, and in Dzikoje by 10%.

In Ukraine, up to the end of the last millennium, local people mowed many Aquatic Warbler breeding sites in the floodplain of Pripyat river. This has slowed down the transformation from low, open sedge vegetation to Reed and shrub communities, attributed to large-scale drainage and eutrophication. Nowadays, mowing of mires has almost ceased.

▲ **Fig. 3.13**
Succession of bushes in the Chełm Marshes, Poland (photo: J. Krogulec).

▼ **Fig. 3.14**
Distribution of main habitat types in Zvaniec, Belarus, in 1950 (left) and 1996 (right) (after Schäffer et al. 2002a).



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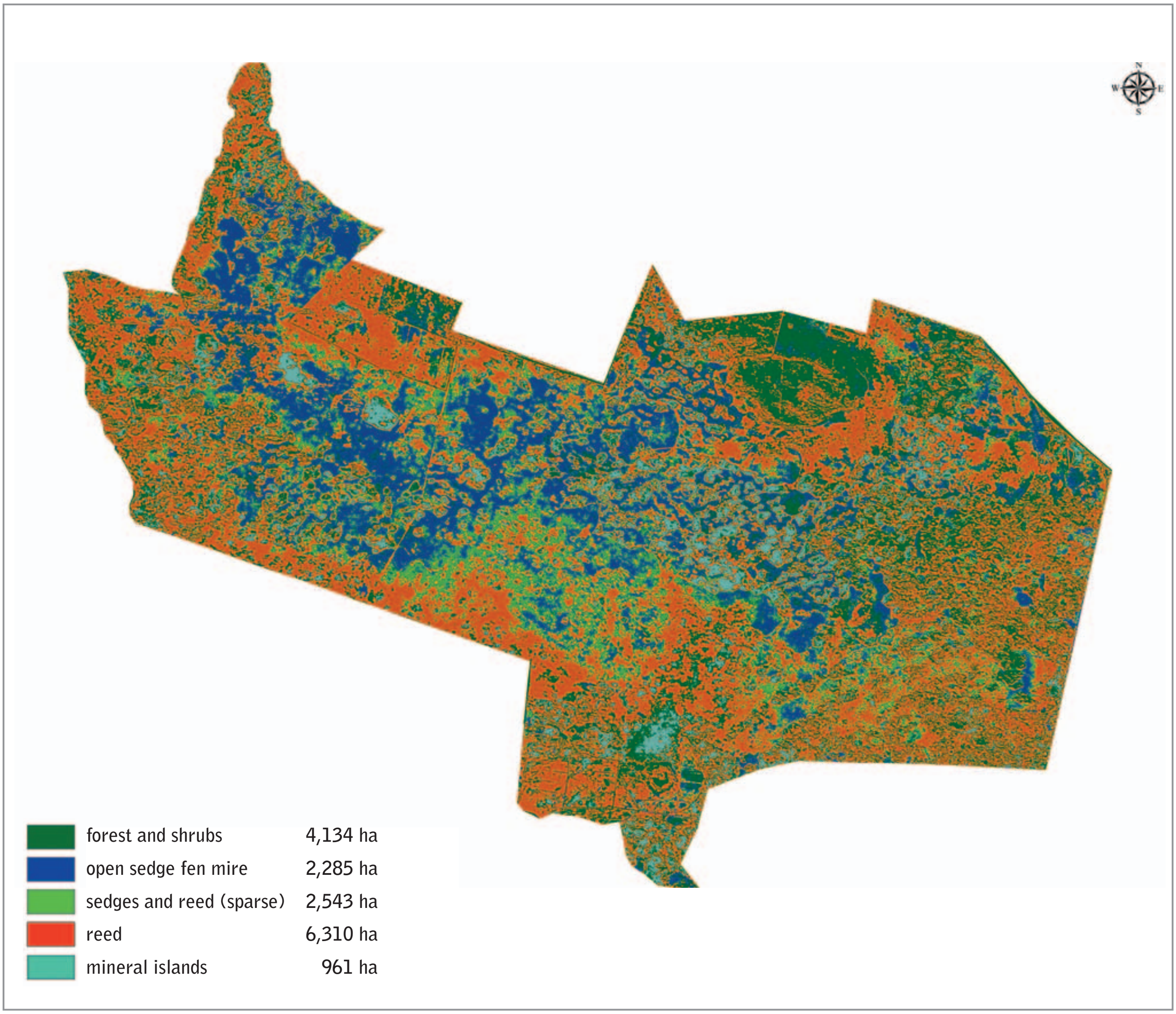
◄ **Fig. 3.15**

Overgrowth with bushes in Zvaniec, Belarus (photo: A. Kozulin).

▼ **Fig. 3.16**

Vegetation map of Zvaniec, Belarus, based on ERDAS satellite images, 2017 (prepared by A.A. Kozulin & A.V. Kozulin).



Unsuitable land use and uncontrolled burning

While most current Aquatic Warbler sites are rather threatened by the abandonment of low-intensity land use, other sites are still threatened by too intensive or intensified land use through too early or too frequent cutting, or too intensive grazing. This threat is often a consequence of lowered water tables and especially likely in dry years, when farmers can enter areas for mowing already before the birds have managed to finish their breeding activities. A very well documented example is the Freesendorfer Wiesen in Germany, which once hosted up to 30 s.m. (in 1988), but lost its breeding population of Aquatic Warblers in 1998 following an increase in grazing intensity to all year round grazing (D. Sellin pers. comm.; Chapter 4.5). Mowing of Aquatic Warbler sites during the breeding season was an important threat also in the Lower Oder Valley National Park, the last breeding site of the Aquatic Warbler in Germany (**Fig. 3.17**). As this is a eutrophic site, early mowing is needed to maintain suitable habitats. Rotational early and late mowing depending on the presence of Aquatic Warblers may solve this management problem (Chapter 4.4). Typical sites in Poland where this threat occurred in recent years are Mścichy and Laskowiec-Zajki in the buffer zone of the Biebrza National Park, the Ner and Tyśmienica river valleys, and especially the remaining suitable fragments of habitat in Bagno Wizna. Too early mowing of sites occupied by Aquatic Warblers has been also reported for the Nemunas Delta in Lithuania (Knöfler 2012). In most sites, this threat has been addressed by conservation measures, with varying success.

A potential new threat is too intensive land use implemented as a habitat management measure for conservation reasons, e.g. where the prescribed grazing or mowing intensity of agri-environmental schemes is inappropriate for the site in question. These cases can occur either because of the implementation of inflexible one-size-fits-all conservation schemes, or through a misjudgement of the relevant advisory expert. For example, at the Biebrza Marshes the initially prescribed mowing every two years turned out to be too frequent for large parts of the area, while even too infrequent for other parts of the same site. Special vigilance is necessary to ensure conservation measures achieve their intended aims.

◄ **Fig. 3.17**
Freshly mown site occupied by the Aquatic Warbler, Lower Odra Valley National Park, 25.06.2007 (photo: F. Tanneberger).

Burning is often used as a management tool in pastoral agriculture and in reed cutting. Uncontrolled fires, especially in spring and summer and if the mire is very dry, cause severe habitat destruction by burning out the upper peat layer (**Fig. 3.18**). In the Biebrza National Park in 1994 there occurred a 3,000 ha fire, which caused a great deal of soil mineralisation, but uncontrolled burning is more often a direct threat, especially (to birds and nests) during the breeding season. Large spring and summer fires happened also in Belarus, Ukraine, and in Hungary. In Zvaniec, burning of vegetation in spring is performed annually by local people, which damages the site, particularly in dry springs when the flood level is low. In that case, burning destroys the whole upper soil layer including plant roots and insects (BirdLife International 2017a). Also in Sporava, burning of vegetation in spring by local people causes substantial damages to the biodiversity, particularly in years with a dry spring when floods are absent. In contrast, controlled burning in winter or early spring during appropriate water or snow levels can be an appropriate management technique for maintaining the habitat quality and may even allow habitats to be occupied by Aquatic Warblers already in the first breeding season after the fire (see Chapter 4.6). In the Ukrainian breeding sites Hrechyshcha-Shlapan and Liubiaz lake (Upper Prypiat), in 2016 >95% of the habitat was burned (even the sedge tussocks), and Aquatic Warbler numbers decreased.

▼ **Fig. 3.18**
Fen mire in Belarus after a deep peat fire (photo: A. Kozulin).

Other threats

Habitat loss and alterations of the hydrological regime can also occur through inappropriate infrastructure developments, such as the building of roads through or near an Aquatic Warbler site. Typical examples are e.g. the building of Carska Droga, the famous dam road through the Biebrza mires in the late 19th century, which has had and still has a profound impact on the hydrology of the site and has probably caused a part of the site to be lost for Aquatic Warblers. In the 1990s, the plan to build a new road crossing the Odra Valley between Germany and Poland threatened Aquatic Warbler breeding sites on both sides of the border. More recently, the plans to build a bypass for the town of Łomża crossing the Narew Valley threatened a nearby Aquatic Warbler breeding site (near Drozdowo). Whereas the first plan was completely abandoned, the second changed and the site was not affected. Along with the direct effects, also secondary effects, such as increased traffic, housing development, and disturbance are potential threats. Other infrastructure threatening fen mires occupied by the Aquatic Warbler may be energy networks and pipelines. The development of biogas plants may increase the pressure on sites to be mown early in spring/summer to harvest biomass with high biogas yields.

A new threat to the Aquatic Warbler has recently arisen in Poland: pushed by the Polish government, a new coal mine under the Bubnów Marsh in the Polesie National Park has been recently granted concession. The affected area is located close to the Polish-Ukrainian-Belarusian border and includes a Natura 2000 site with one of the largest calcareous fen mires in Europe. Here, 389 s.m. of the Aquatic Warbler were recorded in 2014. Despite of a protest by nature conservation NGOs, exploratory drillings (**Fig. 3.19**) were conducted in 2017 (Grzywaczewski 2016, Grzywaczewski & Kitowski 2018).

Inbreeding is a threat that has not been evaluated yet in the Aquatic Warbler but can potentially limit the viability of its population (see also Chapter 6).

A recent threat to mires globally is climate change. Climate change may affect mires directly, through increased temperature and changed precipitation patterns, and indirectly, through changes in agricultural practices and altered fire regimes. For example, a study from Austria (Essl et al. 2012) demonstrated severe risks induced by climate change for Austrian mire ecosystems, with bogs being most threatened. For central and eastern Europe, it is assumed that heat extremes will increase and that summer precipitation will decrease. Correspondingly, risks of river floods and forest fires will increase (EEA 2017b).

For the majority of world population breeding in Belarus, Poland, and Ukraine, warmer annual mean temperatures (3.5-4.5 °C in 2071-2100 compared to 1971-2000) and higher annual precipitation (10-20%, respectively) are projected (EEA 2014). Whereas such a moister climate is likely to favour fen mires, the warmer temperatures and the reduced summer precipitation are likely to cause an overall negative effect on fen mire abundance and condition, and thus on Aquatic Warbler habitats.

▲ **Fig. 3.19**

Exploratory drilling for coal close to the Bubnów Marsh, Poland, February 2016 (photo: G. Grzywaczewski).

4 Habitat management

4.1 General remarks

FRANZISKA TANNEBERGER & JUSTYNA KUBACKA

Habitat restoration and management are necessary in those ecosystems that are no longer able to buffer disturbance. The ability of an ecosystem to withstand a disturbance, such as fire, flood, or drought, or to regain resistance mechanisms against species that may change major feedbacks after an extrinsic disturbance, is termed resilience. In fens resilience seems to be mainly defined by the ability to regain resistance mechanisms against species such as trees or Sphagna (Jabłońska et al. 2018), and fen mires are among the most resilient ecosystems on earth. Thick layers of peat prove that they have retained their peat accumulation function over thousands of years, often thanks to strong self-regulating capacity. Originally, the Aquatic Warbler probably found its natural habitat in low productivity fen mires, which provided good habitat quality without the need for any human land use (see Chapter 2.3). Undisturbed mesotrophic fen mires remain naturally open for thousands of years thanks to the oscillating peat surface.

However, such sites have almost completely vanished in the European range of this species. Most of today's fen mires hosting the Aquatic Warbler have been artificially drained. Human disturbance is likely to make natural ecosystems less resilient (Gunderson 2000). Even slight drainage or long-term low-intensity land use alters the physical and chemical peat properties in near-natural fens. This leads to a change of vegetation and landscape, with increased cover of litter, tall-growing herbs, grasses (such as Reed), and sedges, and the expansion of dwarf shrubs, shrubs, and trees. Even some of the apparently natural habitats, such as the mires in the Biebrza Valley, are nowadays subject to accelerated successional overgrowth, due to slight changes in the original natural conditions, like site hydrology or trophy levels. As a result, without intervention these fen mires 'seek' a new point of equilibrium different from their original state, such as shrubland or wet forest. Succession is generally faster in southern (warmer) regions than further north, and faster in more nutrient-rich fens (Wheeler & Shaw 1995). With increased drainage and eutrophication, Aquatic Warbler habitats became more land use dependent (**Fig. 4.1.1**). Low-intensity human land use through grazing, hay-making, or reed-cutting combined with occasional fires, has been able to hold back successional overgrowth for hundreds of years. These practices have nowadays become widely abandoned (Chapter 3).

To prevent succession from open fen mire to shrubland or forest, active management measures are therefore necessary (**Box 4.1.1**). Improving the water regime should always have priority. Reducing the intensity of drainage is the most important and cost-effective management measure (Chapter 4.2). In the mesotrophic sites (according to the mire typology of Succow & Joosten 2001), sporadic mowing, grazing, or burning (see Chapters 4.3-4.5) seem to

Box 4.1.1

Mire conservation in Europe – from strict protection to active management, and partly back…

FRANZISKA TANNEBERGER & WIKTOR KOTOWSKI

In Europe, nature conservation was initially merely confined to protection. Reserves were established and 'left to fate', with the idea that species and habitat diversity would be conserved spontaneously. Existing human activities, such as cutting reeds for thatch, hay-making in fens, or grazing, continued, however, often as an economic necessity. Such land use, combined with occasional fires, has been able to hold back successional overgrowth for hundreds of years. It gradually became clear that many prized and species-rich communities in northwestern Europe, such as fen meadows, reedbeds, and heaths, only existed because of long-term human use. This insight led to a revolution in nature conservation in the Netherlands by 1945, where Victor Westhoff, against the current belief in the country and Europe at large, developed the idea that it was not enough to simply acquire and preserve nature reserves, but it was also necessary to actively manage them (Westhoff 1945, 1952). ►

be sufficient to maintain Aquatic Warbler habitats (AWCT 1999, Kozulin & Flade 1999). The majority of sites are managed by mowing, and only very few breeding sites are managed over a longer period of time by grazing or controlled burning. Management requirements for eutrophic sites are different: moderately rich sites depend on annual late land use (Kloskowski & Krogulec 1999), and rich sites on annual early land use (Tanneberger et al. 2008). Eutrophic sites are the largest management challenge, as nesting sites need to be protected. The solution is rotational land use that maintains a mosaic of early and late mown areas (see **Box 4.4.2**).

In addition to management being oriented towards maintaining current breeding sites ('maintenance management'), it may be necessary to implement management to restore former breeding sites that have become unsuitable through a lack of management in the past ('restoration management'). In such a situation, it will be necessary to temporarily go beyond the normal management practice for a site of a specific trophic level. This may include the removal of bushes (see Chapter 4.3) and a more intensive mowing regime to restore unsuitable sites to suitable conditions. During the implementation of restoration management (e.g. annual early mowing), a site might be unsuitable for breeding Aquatic Warblers, so it should only be implemented on sites that are currently not occupied by the species, and should be stopped and replaced by normal maintenance management as soon as the species appears on the site.

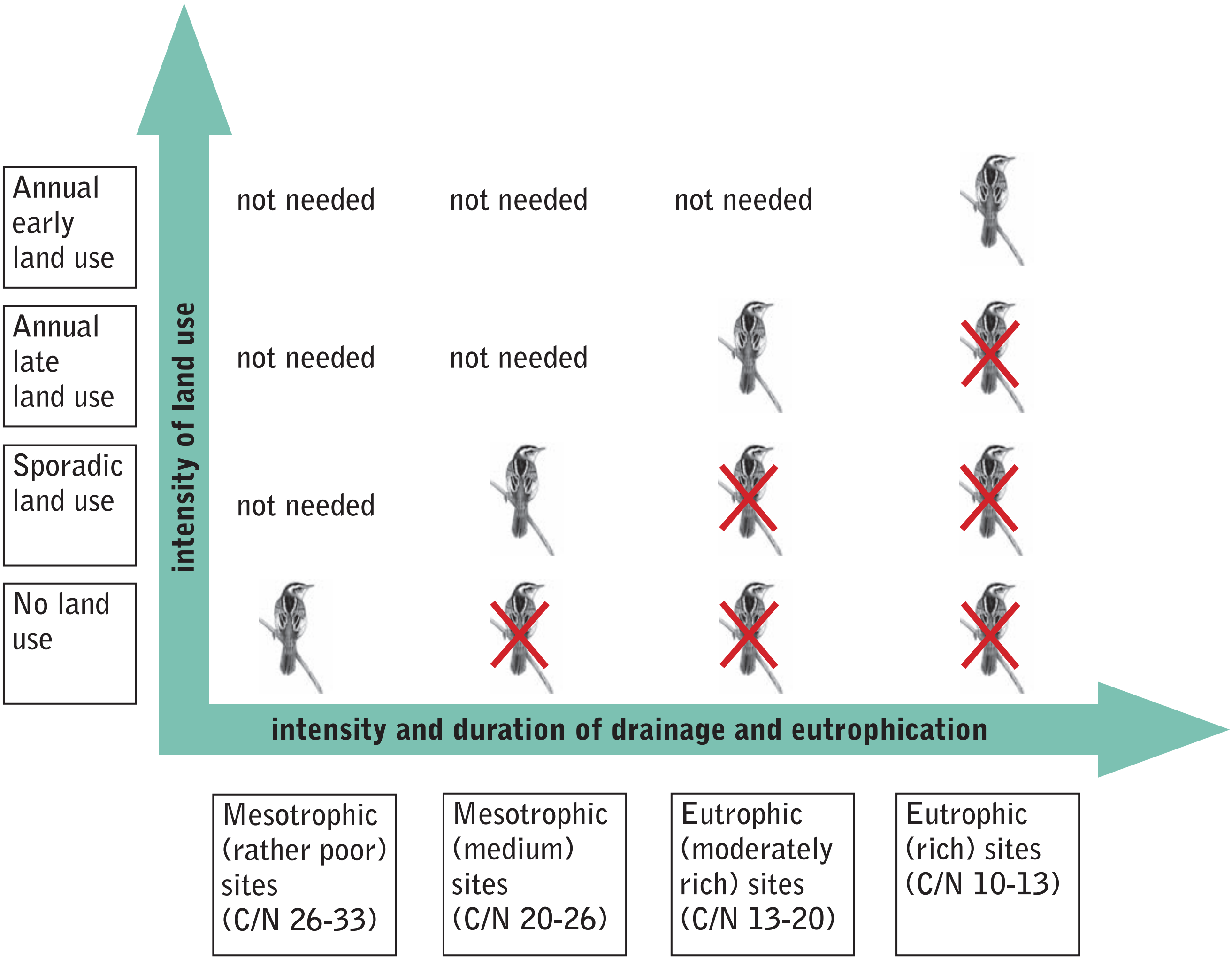
Box 4.1.1 contd His key concept was the semi-natural landscape, where flora and fauna are largely natural, but the structure and species composition of the vegetation has been changed by humans as a result of centuries of land use (van der Maarel & Schaminée 2001). Slowly, with some more attention after the 1970s, conservation changed from 'nature protection' to 'nature management' in many other countries (Tanneberger et al. 2017a).

For example, in Poland, strict protection of peatlands without land use was still being advocated in 1972 by Mieczysław Jasnowski, who argued that the only means of protection appropriate for mires was a strict nature reserve. Some 27 years later, Kazimierz Tobolski observed that the establishment of nature reserves led to the degradation of vegetation in many areas because of a lack of low-intensity agriculture and disturbances to the original water regimes, with low-intensity management being reinstated (Kotowski et al. 2017).

The removal of shrubs and trees that invade formerly open areas, and the mowing and removal of biomass are currently typical conservation measures to preserve semi-natural peatland ecosystems. These management actions are necessary particularly when suboptimal hydrological conditions (e.g. shallow drainage, changed peat hydraulic properties, or increased influence of surface water supply) are associated with increased atmospheric nutrient deposition. Cutting and mowing can be effective in restoring populations of fen plant species, and are now generally recommended in fens. In many countries, special agri-environmental schemes have been developed to fund such management (Chapter 5).

This approach should, however, be avoided in the (quite few) areas that have retained a natural resistance and resilience to tree encroachment (**Fig. 2.1.2**), because once cut, trees and shrubs tend to regrow rapidly, making subsequent mowing management increasingly necessary (Tanneberger et al. 2017a). Concerns have also been aroused recently about the use of tracked mowers, introduced on a large scale in the Biebrza National Park, because at least in the short term, they decrease fen microtopography, change plant functional diversity (Kotowski et al. 2013b), and may cause eutrophication (Banaszuk et al. 2016). Also in the context of the long-term population stability of the Aquatic Warbler, one should consider how management affects the resilience of mires and management should only be performed to prevent successional overgrowth reaching a point when it yields habitat unsuitable for the Aquatic Warbler (see also **Box 2.5.2** in Chapter 2.5). Otherwise, although mowing or removal of trees will increase nest densities, it might be at the cost of possibly still existing natural resilience mechanisms of the mire. This 'over-management' could also make a large part of the population vulnerable to changes in the socio-economic systems which currently finance conservation mowing.Overall, the prospects and costs of restoring natural resilience should be more intensively considered in habitat management.

4.1



▲ **Fig. 4.1.1**

Model of the occurrence of Aquatic Warblers under natural conditions and at three stages of increasingly intensive and long-term drainage and eutrophication in relation to the intensity of land use. 'not needed' means no necessity of a given type of management (mire typology according to Succow & Joosten 2001; from Tanneberger 2008**).**

▲ **Fig. 4.1.2**
Central part of the Ławki Mire, Biebrza National Park, Poland, where suitable Aquatic Warbler habitat conditions are maintained without mowing, August 2012 (photo: F. Tanneberger).

4.2 Water management

FRANZISKA TANNEBERGER, JUSTYNA KUBACKA, JOCHEN BELLEBAUM, MAREK DYLAWERSKI, VIKTAR FENCHUK, LARS LACHMANN, ALEXANDER KOZULIN & JAROSŁAW KROGULEC

The quantity and quality of water are critical to fens, playing a major role in determining the type of fen, vegetation, and wildlife, as well as what products can be harvested, and the further social and economic benefits provided by fens (McBride et al. 2010). In particular, drainage has severe long-term effects, but changes in fen water chemistry also substantially affect site conditions and species composition. Understanding the basics of fen hydrology is, therefore, essential to successful fen management. Restoring suitable water conditions considerably reduces the need for vegetation management, which makes water management a cost-effective management tool (Flade & Lachmann 2008).

This chapter looks at water management at Aquatic Warbler breeding sites. The restoration of abandoned sites or the creation of new breeding sites is described in Chapter 4.7

Water quantity

The water level in the breeding area is of the utmost importance for the Aquatic Warbler, as it determines the stability of the whole fen mire ecosystem. Most breeding habitats of the species have disappeared due to the drainage of fen mires and floodplains, whether to claim them for (intensive) agricultural use or forestry, or to excavate peat. Drainage naturally results in changes to the water regime in the area (Chapter 3; Flade & Lachmann 2008). Once a peatland is drained, peat consolidation, compaction, and oxidation lead to changes in the hydrological and hydraulic conditions, and consequently mire development may be permanently affected. Draining a wetland has a devastating effect because it compromises the area's resilience, or in other words, it makes the wetland unstable. Typically, drainage will induce plant succession, mainly the growth of shrubs and trees (such as willow and birch), which further accelerates drainage through increased evapotranspiration (Flade & Lachmann 2008). Drainage also causes eutrophication due to peat mineralisation (Chapter 3).

Naturally, percolation fens have an almost constant water table relative to the surface. Whereas young percolation fens are susceptible to water table fluctuations, with growing peat thickness fluctuations in water supply and loss are increasingly compensated by mire surface oscillation (Joosten et al. 2017). Fen mires inhabited by the Aquatic Warbler are, to a varying extent, affected by anthropogenic disturbance (Chapter 3). Many of them are fed by both ground and surface water, and annual dynamics of the water regime vary with precipitation. In the key Belarusian breeding sites, the following pattern has been observed: During spring flooding (March/April) a high water table 10-50 cm above soil surface, in May-July close to the soil surface, in August-September 20-30 cm below soil surface (A. Kozulin pers. comm.).

Unsuitable water levels and trophic states have direct effects on the density of singing males (**Fig. 2.3.13**) and on breeding productivity. Excessively high water levels will cover tussocks on which females place their nests, increase the flooding risk for nests and could limit foraging areas. Insufficiently high water levels are supposed to reduce arthropod abundance (A. Kozulin pers. comm.), make a fen more accessible to mammalian predators (e.g. foxes, raccoon dogs, weasels, or stoats), and, by promoting the encroachment of shrubs and trees, reduce the area of habitat available for nest placement and foraging.

Therefore, the need to ensure suitable water levels in Aquatic Warbler breeding sites is emphasised in the International Species Action Plan for the Aquatic Warbler (Flade & Lachmann 2008). Action 2.4, with priority classified as 'essential', reads: *"Create favourable hydrological conditions* *at the sites used by the Aquatic Warbler, either through restoration of natural hydrological conditions or through suitable management of new or existing hydrological infrastructure."*

The restoration of a near-natural hydrological regime can be done, for example, by closing drainage ditches and channels, filling up ditches and channels with local material (e.g. peat), and restoring the water regime in entire catchment areas. Reports on restored fen mires are, for example, in Grootjans et al. (2012), Wagner & Wagner (2005), and Kozulin et al. (2010). Examples of Aquatic Warbler sites are rare – probably the northwestern part of Dzikoje (Belarus) as well as Błota Serebryskie (Chełm Marshes, Poland) can be considered as restored near-natural regimes. Both are described in a case study below.

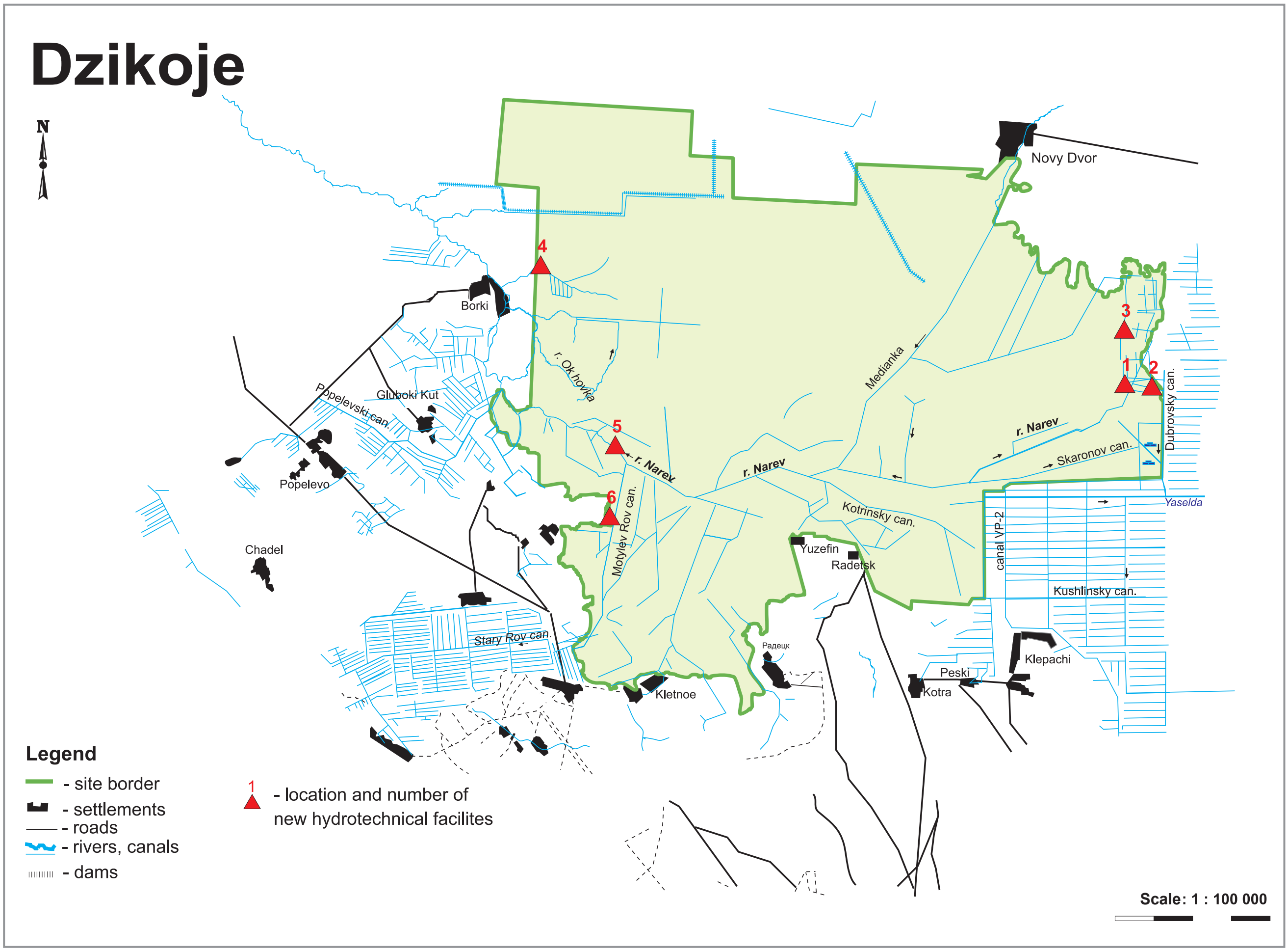
Water level management of new or existing hydrological infrastructure to favour Aquatic Warbler breeding conditions has been implemented in several breeding sites. Here the following examples are presented: Zvaniec (Belarus), Nemunas Delta (Lithuania), and Lower Oder Valley National Park (Germany).

Case studies for the restoration of near-natural hydrological conditions

Dzikoje (Belarus)

Dzikoje is a large mesotrophic fen mire with an area of >20,000 ha, located on the watershed of the Baltic and Black seas. Already protected as a hydrological nature reserve, it was included into the national park 'Bielaviežskaja Pušča' in 2000, which made it the most renowned Aquatic Warbler breeding site globally, holding the titles of UNESCO World Heritage Site, Biosphere Reserve, Ramsar Site, and Important Bird Area. Dzikoje is the third most important Aquatic Warbler breeding site in Belarus, supporting the population

▼ **Fig. 4.2.1**
Hydrological restoration works implemented at Dzikoje in 2006 (map prepared by Nikolai Shevtsov).



4.2

of c. 150-170 s.m. (see also Chapter 2.2). The Aquatic Warbler has a patchy distribution and is highly localised in the western part of the mire (Fenchuk & Cherkas 2009) with an area of occuppancy of only 1,200 ha (Malashevich 2013). In 2002, the management plan for Dzikoje was developed (alongside with Zvaniec and Sporava, see below), identifying hydrological restoration as one of the key areas for conservation (Schäffer et al. 2002b). Urgent actions were implemented in 2006 as part of a project financed by the Darwin Initiative (UK). In total six dams were built, mostly in channels in the periphery of the mire. Three of them are located in the western part (**Fig. 4.2.1** and **4.2.2**), including one dam blocking the Narau River. They affect the hydrological regime of the area occupied by the Aquatic Warbler. Full counts of the Aquatic Warbler conducted in 2007, 2008, 2013, and 2016 (Malashevich 2016 and pers. comm.) showed that the Dzikoje subpopulation was stable in this period. At the same time, recent observations and retrospective satellite image analyses show overgrowth of the mire by shrubs during the last two decades (Grummo2015),including areas previously occupied by the Aquatic Warbler (A. Kozulin pers. comm.). Due to the lack of Aquatic Warbler distribution data for the period before 2007, it is impossible to assess the longer-term trend.

▼ **Fig. 4.2.2**
Dam built in 2006 in the western part of Dzikoje (photo: A. Kozulin).

A northwest shift towards wetter and richer areas is likely. In 2016 the situation at Dzikoje was reassessed and a new conservation plan developed (Grummo 2017), leading to a new engineering project to be completed by the end of 2018 and implementation planned for 2019 (financed by Frankfurt Zoological Society, Germany).

Błota Serebryskie (Poland)

One of the best Polish examples of an Aquatic Warbler site with a restored near-natural water regime is Błota Serebryskie (241 ha). It is located in Southeast-Poland and belongs to the Chełm Marshes. The mire was drained in the 1970s and used for hay-making by the former collective farm 'Przyszłość' ('Future') in Serebryszcze. It was divided by a drainage channel and dike into two parts. The western part was severely drained, ploughed, sawn with grasses and utilised for hay-making. The eastern part was only partly drained and eventually left abandoned. In the 1980s, the entire site became abandoned and especially in the western part overgrowth with shrubs started. In 1991 the occurrence of Aquatic Warblers at Błota Serebryskie was confirmed, and a Chełm Marshes Action Plan for habitat restoration was prepared with financial support of the RSPB. A project developed by OTOP, IUCN Poland, and the Nature Conservator of Chełm to implement water management works (damming drainage channels) started in 1995 (**Fig. 4.2.3** and **4.2.4**). The project focused on the eastern part (**Fig. 4.2.5**). Vegetation changed from *Cladium mariscus* dominance (in 1971 before drainage) to *Molinia caerulea* stands with little *Cladium mariscus* in 1998. In 2016 *Cladium mariscus* rushes covered already again some 130 ha. Moreover, rewetting of the eastern part had a great influence on the western part of the site: The combination of both hydrological restoration and adequate management (agri-environmental schemes, since 2007 offering an Aquatic Warbler protection package) favoured habitat regeneration both in the eastern but also in the western (previously severely degraded) part. In 1997 only 9 s.m. were

recorded in the *Cladium mariscus* patches of the eastern part. During census in 2009 already 62 s.m. were recorded: 16 in the eastern part and 46 in the western part. The most recent full census in 2014 yielded 118 s.m. (48 in the eastern and 70 in the western part, respectively). The strong increase of Aquatic Warbler numbers is a result of both improved water management and proper habitat management (i.e. shrub removal, adequate mowing, and leaving some parts unmown). The basic objective was to restore the near-natural water regime of this site.

▲ **Fig. 4.2.3**
(top left) Dam on the Gdolanka channel, Błota Serebryskie, Poland, 1996 (photo: J. Holuk).

▲ **Fig. 4.2.4**
(top right) New damming in 2008 to restore the old dam built in 1996, Błota Serebryskie, Poland (photo: J. Holuk).

▲ **Fig. 4.2.5**
View on the eastern part of Błota Serebryskie, Poland, May 2012 (photo: J. Krogulec).

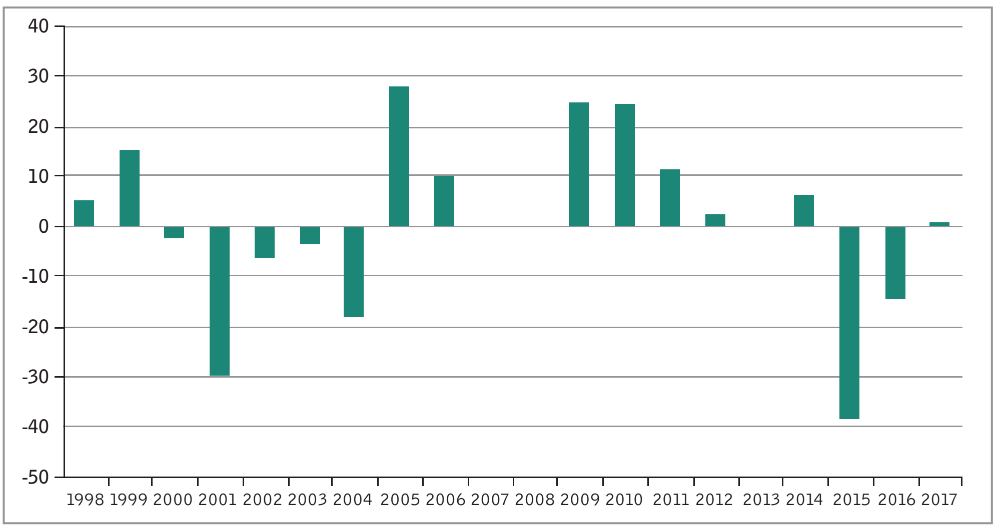
4.2

Case studies for managing water quantity with new hydrological infrastructure

Zvaniec (Belarus)

This fen mire is one of the key Aquatic Warbler breeding sites, holding c. 25% of the global population (see Chapter 2.2). The Zvaniec Mire is the remaining fragment of a once huge fen mire complex located in the upper course of the Prypiac river. The mire is surrounded by large meliorative systems, created at the end of the 20th century, which significantly affect the hydrological regime of the site. The succession from an open sedge fen mire to sedge communities with shrubs and reeds has been documented for the period 1950-1996 (**Fig. 3.14**). Zvaniec was one of the first three sites in Belarus to have a management plan (prepared in 1998 with funding from the Darwin Initiative, UK). In 2002 the first activities to improve water management were planned. In 2003 practical work started on the regulation of the hydrological regime (**Fig. 3.9**). The period 2000-2004 was very dry (**Fig. 4.2.6**), facilitating uncontrolled spring fires and overgrowth with shrubs. To prevent drainage all inner channels draining the mire in the North and East were closed with sluices (**Fig. 4.2.7-Fig. 4.2.9**). Sluices were built in a way to allow for a water table of c. 10 cm above the soil surface in the mire. Starting with 2005 and until 2011, very wet years followed (**Fig. 4.2.6**). During these years, waters from the Orekhovsky channel and from pumping stations of the meliorative systems surrounding the mire supplied the site with excess water, leading to a water table at the level of tussock tops during much of the vegetation period. It is assumed that this facilitated fast spreading of the Reed. To regulate the water table in wet years, dams and additional sluices were built, which allow for controlling the supply of surface water. Water management was tackled in several projects, funded by UNDP/GEF, ClimaEast, and most recently (since 2017) the EU LIFE programme. Overall, it was aimed at sustaining the optimal water level in the mire over seven or eight years out of ten (excluding years with extreme draught). Target water levels vary between high (level of tussock tops) in

▲ **Fig. 4.2.7**
New sluice built at a key channel impacting Zvaniec, Belarus, April 2006 (photo: A. Kozulin).



► **Fig. 4.2.6**
Mean water table (in cm above or below soil surface) during the vegetation season (May-July) on the Zvaniec fen mire in the period 1998-2017 (data: A. Kozulin).

March-April, close to soil surface in May-July, and low (10-30 cm below soil surface) in August-October. The infrastructure now allows the active regulation of the water table in substantial parts of the peatland (Kozulin & Tanovitskaya 2017). Still, vegetation mapping in 2017 showed that the trend to overgrow with bushes and Reed has not been reversed, and has possibly even been enhanced (**Fig. 3.16**). This is possibly also related to water quality (see below). Given that the current Zvaniec Mire is only a remnant of a much larger mire that existed previously, it seems crucial to also assess the opportunities for raising water levels in the catchment area.

▲ **Fig. 4.2.8**
Rock-filled dam to stabilise water levels at Zvaniec, Belarus, June 2010 (photo: A. Kozulin).

◄ **Fig. 4.2.9**
Sluice at the 'Novoselki' fish farm, which is situated on the territory of the formerly huge Zvaniec Mire, Belarus, March 2005 (photo: M. Maximenkov).

Nemunas Delta (Lithuania)

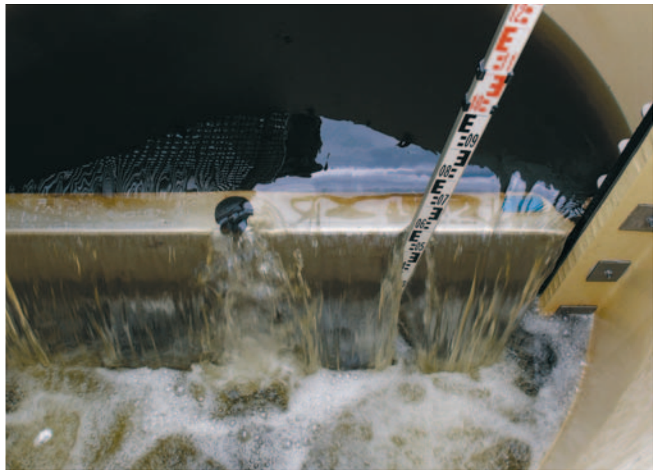
Aquatic Warbler breeding sites in the Nemunas Delta illustrate the challenges of water management in polders, the potential for collaborative approaches between farmers and nature conservation, and the need for permanent coordination and calibration. The Tulkiaragė Polder (c. 470 ha) was intensively used for hay-making during Soviet times, but was later abandoned for nearly 20 years. It used to be an important Lithuanian Aquatic Warbler breeding site, but by 2010 there were probably only a few individuals. The area is located close to an important Lithuanian breeding site, the Šyša Polder, and still has patches of similar sedge habitat. In the LIFE+ project 'Baltic Aquatic Warbler' (2010-2015), the water regulation infrastructure was restored. Dikes were repaired in order to stop uncontrolled water flow into the site, water gates controlling water inflow were reconstructed, and the abandoned water pumping station building was renovated (BEF 2017). After the project, it became clear that dikes need much more substantial reconstruction, as they are prone to destruction by floods and beavers. Currently, water level management in Tulkiaragė is not controlled. The local farmer adapted to this situation by changing his mowing strategy: he equipped several tractors with double-wheels, constantly monitors weather conditions, and mows with several tractors at once in order to perform quick mowing in a relatively large area within a short window of opportunity. As mowing is anyway performed rather late, by that time in most of the area birds have finished their nesting season.

Water management at the Šyša Polder (c. 750 ha; **Fig. 4.2.10**) was tackled under the same project, and then continued within the project 'LIFE MagniDucatusAcrola' (2016-2022). The polder is primarily used for farming, and in favourable years holds 30-50 s.m. The optimal water level management to meet Aquatic Warbler conservation and farmers' needs was identified (BEF 2013). The polder (as well as other polders important for the Aquatic Warbler in Lithuania) needs clear priority setting to balance the interests of fishery, nature conservation, and agriculture. These interests, in particular fishery, are potentially conflicting with each other. Late pumping in spring (to favour fish spawning) causes disadvantages for farming and Aquatic Warbler breeding. In such years, Caricetum distichae (optimal for the Aquatic Warbler habitat) is replaced by Caricetum gracilis or Phalaridetum arundinaceae, which are less suitable as an Aquatic Warbler habitat. Too early pumping, by contrast, is also unfavourable, as it leads to sedge communities being replaced by grasses. Among farmers, there are those willing to cooperate and others that are not interested. In order to balance different interests and priorities, the LIFE MagniDucatusAcrola project will set up additional water sluices, which will enable more fine-tuned management of the water level in priority sites for Aquatic Warbler conservation. Additional water pumping will be performed by a special mobile water pump. Water management will be fixed in conservation agreements with the farmers: optimal water level for the Aquatic Warbler will be maintained during its breeding season, while during mowing activities, water can be more intensively drained to facilitate mowing and drying hay. Such system requires the permanent coordination and calibration of water pumping, involvement of conservation officers, and should be based on long-term conservation agreements with farmers (BEF 2017). Experience from the Šyša Polder shows that after years with unfavourable water levels (2013: late flood and delayed pumping, decrease of Aquatic Warbler numbers from 30 in 2012 to only 5), good water management can allow for recovery of Aquatic Warbler numbers (13 in 2014, 24 in 2015).

▼ **Fig. 4.2.10**
Renovated pumping station at the Šyša Polder, Lithuania, 2011 (photo: Ž. Morkvėnas).

Lower Oder Valley National Park (Germany):

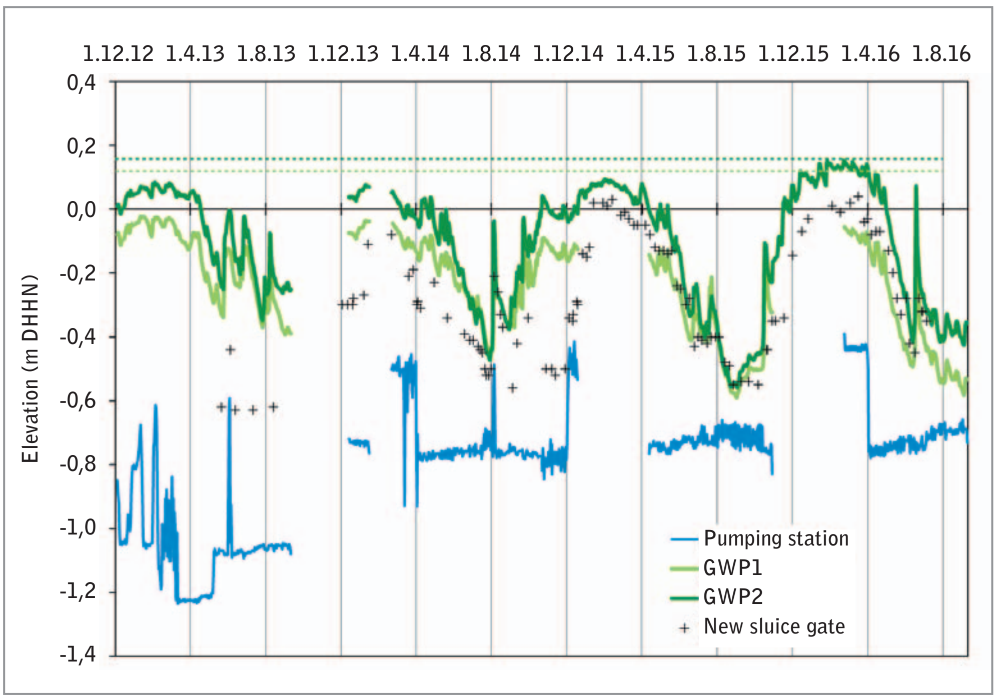
Breeding numbers in the Lower Oder Valley National Park declined in the past due to habitat loss and brood destruction while mowing. A testing and development project was implemented in 2009-2014 to protect and restore habitats of the Aquatic Warbler. Water tables were raised on c. 200 ha, by installing new sluice gates (**Fig. 4.2.11-4.2.13**), and grassland management was adapted to create a favourable habitat for Aquatic Warblers. The sluice gates were developed to maintain a minimum water level of 40 cm below the surface of the soil. At the project sites, the groundwater table dropped at the start of the vegetation period because of evapotranspiration, and increased with precipitation (**Fig. 4.2.14**). In the course of the breeding season, the groundwater table dropped repeatedly to 30-50 cm below the surface of the soil, allowing farmers to use the area. If needed, water tables can still be actively lowered to facilitate mowing. In case of a persistent drought during the breeding season (as in June/July 2014), the water table in the ditch and in the polder is substantially higher than in the ditch system not influenced by the weir (**Fig. 4.2.14**). The Aquatic Warbler occupied the site in 2010 and in 2012-2014, with 2-3 s.m. annually. The management plan for the National Park aims to continue the newly established dynamic grassland management approach.



▲ **Fig. 4.2.11**
(left) Installation of a sluice gate at the polder near Gartz, Lower Oder Valley National Park, Germany, winter 2012/2013 (photo: J. Bellebaum).

▲ **Fig. 4.2.12**
(right) View inside a newly installed sluice gate at the polder near Gartz, Lower Oder Valley National Park, Germany, May 2013 (photo: J. Bellebaum).

◄ **Fig. 4.2.13**
High water table in the polder near Gartz, Lower Oder Valley National Park, Germany, February 2014 (photo: J. Bellebaum).



◄ **Fig. 4.2.14**
Water levels at the pumping station and one of the newly installed sluice gates during testing (from 1 May 2013) and during the operation phase (from 6 January 2014) together with ground water tables at two gauges (GWP1/2) in the project site influenced by the weir. Dashed lines indicate surface levels at the gauges.

4.2

Box 4.2.1
Recommendations for a better understanding of fen hydrology

Based on McBRIDE et al. 2010

Recording appropriate information is essential when comparing the target with the current hydrological regime. Conditions should be monitored during critical periods within the year, e.g. the spring floods and the summer period with the lowest water levels. To take account of year-to-year variability, hydrological conditions should be monitored over a number of years (ideally ten or more) to develop an appreciation of the longer-term hydrological regime, including both extreme wet or dry years, and those that are more typical in hydrological terms (McBride et al. 2010).

The value of regular field measurements of water quality parameters is high: the temporal variation of base-richness (pH), mineralisation (electrical conductivity), and dissolved oxygen, all of which can be measured using hand-held meters, can provide valuable information on the seasonal variation of water sources to a site. More comprehensive information on water quality is more powerful in terms of understanding the functioning of a site, though there is a trade-off in terms of cost. A common strategy is regular (e.g. weekly or fortnightly) field measurements, supplemented by much lower frequency (e.g. annual) laboratory analyses of samples (Mc Bride et al. 2010).

Looking at the fen type and catchment land use and making broad assessments of water sources and vegetation communities can be sufficient for informed management. However, in some cases greater detail on the water and peat chemistry of a site is needed in order to understand what might be causing enrichment and how to tackle it. Changes in nutrient status could be gauged initially by the encroachment of nutrient tolerant species. The occurrence of some key undesirable species may be sufficient to warrant a more detailed investigation of nutrient levels in the fen (Mc Bride et al. 2010).

Sample locations should track the pathway of nutrient input to the fen, and nutrient migration through the fen. The first set of samples will form the baseline for subsequent monitoring, and it is a good idea to take as many as practically and financially possible. This may show that there is little variation across the fen and, if so, fewer samples could be taken during the next round of monitoring. The baseline may also detect variations and nutrient 'hotspots' where the number of sampling points needs to be increased (Mc Bride et al. 2010).

Water quality

Repairing the hydrological regime of peatland is more complex than simply raising water levels. In groundwater-fed fens, in particular, increasing water levels may lead to acidification if the discharge of base-rich groundwater cannot be reinstated. Therefore, the successful management of groundwater-fed fens should be approached on a broader scale that includes the landscape-scale management of groundwater systems. Not only quantitative, but also qualitative aspects are important (Grootjans et al. 2012). Monitoring is key to understanding the status, condition and management options of a specific sites (see **Box 4.2.1**).

In Aquatic Warbler breeding sites, in particular the water supply by (nutrient-rich) surface waters is a management challenge. Here, the following examples are presented: Zvaniec (Belarus) and Rozwarowo Marshes (Poland).

Case studies for managing water quality

Zvaniec (Belarus)

Since 2002, major efforts have been made to improve water levels at Zvaniec (see above). These activities have focused on stabilising water levels, using nutrient-rich surface waters of the drainage system (**Fig. 3.9**). In particular, the Orekhovsky channel and two meliorative systems (Travy and Orekhovskaya) bring water to the central part of Zvaniec. This water has a high ion content (mineralisation 370-420 mg/l). Along the channel, a belt of c. 400 m is rapidly overgrowing with Reed. Within the project 'LIFE MagniDucatusAcrola' (2016-2022), it is planned to repair existing, and build new water regulation structures, which are hoped to allow to actively adjust not only the level, but also the quality of the water. To improve the quality of the water, it will be directed through the periphery of the mire, where it will be purified before affecting the central part of the mire. There are also plans to improve water quality by directing surface water from the catchment (Radostovo forest) to the mire (A. Kozulin pers. comm.). This part of the catchment was separated from the mire in the 1990s.

Rozwarowo Marshes (Poland)

The Rozwarowo Marshes are located 15 km from the Baltic Sea, between Kamień Pomorski and Wolin (Northwest-Poland). It is the largest Pomeranian breeding site, with some 30 s.m. still around the year 2010 (see Chapter 2.2). Grzybnica river divides the peatland into two parts and flows to the Baltic Sea. The water levels are largely artificially managed by three landowners, mainly for winter reed cutting. The peatland is c. 7 km long and 3 km wide and is surrounded by agricultural land (**Fig. 4.2.15**) and some forest. In recent years, it is assumed that very nutrient-rich water brought to the site, especially from Kanal Rozwarowski (from some 5,000 ha intensively farmed land, partly drained peatland) and Wołczenica river (from distant urban areas) negatively affect habitat quality. In addition, the artificially lowered water levels in winter lead to peat degradation and increased nutrient loads in the Grzybnica and, consequently, in coastal waters. Eutrophication has probably caused the rapid deterioration of Aquatic Warbler habitats, despite the implementation of previously suitable management (winter mowing; Tanneberger et al. 2009). Most conspicuously, the height of vegetation on some monitoring plots almost doubled between 2006 and 2013. In 2013, c. 75% of all suitable Aquatic Warbler habitat in 2005 was lost (Tanneberger et al. 2014). A project funded by the Baltic Sea Conservation Foundation (BaltCF) in 2016-2018 has prepared an analysis of the hydrotechnical system and the hydrochemical status. Water quality was studied at four main water courses supplying the site. Excess of total N, and especially N_{NO3}, total P, and P_{PO4} was particularly high at Wołczenica river and in the Southwest. The water entering the peatland from the eastern side (Grzybnica river and Kanal Rozwarowski) has particularly high electrical conductivity values (>2,000 μS/cm; Gliźniewicz et al. 2017). Based on this, two dams have been built to direct nutrient-rich waters through the reedbeds on the periphery of the site before affecting the central part. The project also is preparing a mid- and long-term strategy for the management of this site (M. Dylawerski pers. comm.).

▼ **Fig. 4.2.15**
Maize farming in close vicinity of the Rozwarowo Marshes, Poland, June 2013 (photo: F. Tanneberger).

4.3 Shrub removal

PIOTR MARCZAKIEWICZ

Although all the major Aquatic Warbler breeding sites are protected by law, the habitat area is shrinking due to secondary plant succession, which eventually leads to the encroachment of bushes and trees (Chapter 3). In the time before widespread agricultural use of mires and related drainage, fens remained open due to their specific natural water regime and natural disturbances (wild ungulates, fires, and floods). Later farmers traditionally kept shrubs in check by grazing and mowing. Changes in agricultural management practices in recent decades have resulted in many fen communities converting to scrub and wet woodland. The restoration and maintenance of habitat in this succession stage requires bushes to be removed (this chapter), and typically requires regular mowing afterwards (Chapter 4.4).

Shrub removal is generally performed by hand or with a machine. Hand tools include a chainsaw, a clearing saw (brush -cutter), a saw, an axe, or a machete. Hand removal is usually applied to trees and bushes with a relatively large diameter (⩾10 cm) growing in a small area. Typically, the cut biomass is removed. A disadvantage of this method is its labour-intensiveness and high cost. Hence, it is normally used only in cases when using a machine is not possible. Machine removal is typically applied for shrubs with a small shoot diameter (<10 cm). These shrubs are usually scattered and surrounded by herbaceous vegetation. In this kind of area, mowing (if herbaceous vegetation is cut) and bush removal (when lignified stems are cut) can be performed with one machine. Since measures for Aquatic Warbler conservation are aimed at halting succession, both mowing and shrub removal are typically applied at the same time, because areas without bushes and willows will not normally require active management, provided that the amount of nutrients is not high (see Chapters 3 and 4.1). Consequently, the difference between shrub removal and machine mowing is often small, and equipment used to this end must feature both functions.

Experience from the Biebrza Valley

There are several types of devices and vehicles used for shrub removal. At the beginning, in the Biebrza Valley, a four-wheel-drive tractor with twin wheels and an attached rotary brush cutter were used. The cutter, equipped with two blades rotating horizontally at a high speed (about 500 rpm), could easily cut and shred all offshoots and even thick young trees several centimetres in diameter (though thicker and higher trees are not shredded that well). Shredded vegetation was left on the ground. The main disadvantage of this solution is the heavy weight of the set and the high pressure on the ground. The high power necessary to operate in difficult terrain and propel the cutter can only really be provided by large and heavy tractors. Although twin wheels diffuse pressure onto a larger area, this has proved insufficient and bush removal with tractors can only be performed on drained or frozen ground (and ruts are still created). Another problem is that the cut biomass could not be collected and was left on site. Since the operation of piste-basher mowers started in the Biebrza Valley, tractors have been rarely used in Aquatic Warbler habitats, mainly for the removal of biomass during winter on frozen ground.

During the LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (2005-2011), a different solution was used to perform management activities: an innovative machine, converted from a piste-basher (snow groomer) – a caterpillar-tracked vehicle used for grooming ski slopes. Originally designed for operation on snow, it also works very well on peatlands. With pressure on the ground not exceeding 60 g/cm^2 (which is less than that of a human), it can work even in high water table conditions, as was demonstrated on the Biebrza Marshes in the extremely wet 2010 season. The cutting head can be installed at the front, with the height able to be regulated by the driver. Thanks to this, it is possible to adjust mowing height to local conditions, for example raise it in places with sedge tussocks and lower it in places with shrubs. First piste-bashers in the Biebrza Valley were equipped with a variation of the flail mower – a horizontally-placed drum with immobile cutting blades (**Fig. 4.3.1**). This head proved to be very good for shrubs and trees up to several centimetres thick. It was less effective for cutting sedges, which twisted around the drum. The only way to collect the cut and shredded biomass from the ground was by sucking it in directly after mowing, and then transporting it by a blower to a trailer attached to the piste-basher. This method, however, was not effective for cut lignified plants, which were usually too heavy to be sucked in. A disadvantage of this solution is the high humidity (and corresponding weight!) of the collected biomass; in addition, every time the trailer fills up, the piste-basher needs to drive to a storage place, which causes many passages. It is not economically sound (because of high fuel consumption and low work load per hour) and resulted in the creation of 'roads' in the mire, often with very damaged soil. Additionally, the 'sucking tool' was troublesome in using and maintenance. Therefore, sucking is no longer used for biomass collection, and as this is needed for removing biomass cut with a flail mower, the use of such mowers is no longer allowed on the Biebrza National Park property (but still on private land in the Park, as it is not able to prohibit it there). Without removal, cut and shredded biomass decomposes rather quickly and causes on-site eutrophication, which is not favourable in Aquatic Warbler habitats. In general, the use of flail mowers should be avoided and if at all, it should be only accepted as initial management activity, preparing a site for mowing with tools allowing for biomass collection.

▲ **Fig. 4.3.1**
A piste-basher with a modified flail mower (photo: P. Marczakiewicz).

Another type of a head mounted on the piste-basher is the sickle bar (reciprocating, finger-bar) mower, which mows and deposits cut biomass in between the tracks, so that it is not pressed into the ground. The cut, but not shredded biomass stays above the water and can dry, if the weather allows. To collect biomass after it dries, a second pass by a piste-basher is necessary, this time with a baler. Bales are removed in winter, when the ground is frozen or in autumn if the ground is dry. The sickle bar mower is very effective in cutting herbaceous vegetation, but does not work well for lignified vegetation, which often breaks its blades ('fingers'). A disadvantage of this solution is that it is necessary to enter the mown area three times (mowing, baling, and bale removal). Another head type was first applied in the Biebrza Valley in 2010, after experiments with mowing in previous years. It consists of a set of rotary mowers. The cut biomass is placed and removed in the same way as with the cutter bar mower. The rotary head is able to thoroughly mow herbaceous vegetation and works well with lignified shoots up to two centimetres thick.

The equipment used to carry out management activities in the Biebrza Valley is constantly being tested and improved. This concerns both the mowing heads and the piste-bashers, which were originally dedi-

4.3

► **Table 4.3.1**
A decision-making diagram for the removal of trees, groups of trees, and groups of shrubs (Budka et al. 2013).

Trees, tree groups, and shrub groups that should preferably be removed	Trees, tree groups, and shrub groups that should preferably be retained
The removal of the tree group allows two patches of Aquatic Warbler habitat to be connected	The removal of the tree group does not result in two patches of Aquatic Warbler habitat being connected
The area of the tree group is small	The area of tree group is large
The tree group has an oblong shape and is a narrow strip among open areas	The tree group has a circular shape
It is possible to repeat offshoot removal within the next 3-5 years	It is not possible to repeat offshoot removal within the next 3-5 years
The tree group lies on peat soil	The tree or shrub group lies on a mineral island
There is low tree or shrub density, with vegetation characteristic for open areas in between	The tree or shrub groups are dense and there are no species typical of open areas in between
The tree or shrub vegetation is expansive	The tree groups, shrub groups and single trees are not expansive
The shrub group is in an initial succession stage, trees and bushes above ten years of age are scarce	The shrub group is in advanced succession stage, trees and bushes above ten years of age dominate
There are no conservation arguments for retaining the tree group	There are important conservation arguments in support of retaining the tree group, such as presence of protected plant or animal species

cated to work in winter conditions. The machines must be constructed bearing in mind that all the other devices, such as balers or trailers for biomass removal, must drive on caterpillar-tracked vehicles, and their ground pressure must not exceed that of the piste-basher (i.e. 60 g/cm^2). This can be achieved either by decreasing the weight of the equipment used (calculated including the load, such as the transported biomass) or by increasing the area of contact with the ground (through widening or lengthening the tracks). The number of (modified) piste-bashers operating in the Biebrza National Park in 2016 was more than 23 (only those working on state-owned land need to apply for permission to enter the Park and are recorded).

For the maintenance and restoration of Aquatic Warbler habitats, it is often necessary to decide which groups of shrubs should be removed, and which ones should be retained. To facilitate decision-making, a key was created (**Table 4.3.1**, from the Biebrza National Park management and conservation plan developed in the LIFE project; Budka et al. 2013), which allows the arguments for and against the removal of a given tree or shrub group to be weighed. Not all arguments are of the same weight; for example, even if a given tree group is dense, found on a mineral island, the trees are older than ten years and there are no plants typical for open areas (three arguments against removal), but at the same time it is a narrow strip (a 'fringe') that causes the fragmentation of the Aquatic Warbler habitat (one argument in favour of removal), its removal will still be profitable.

Experience in other breeding sites

Removal of shrubs in other East-Polish Aquatic Warbler breeding sites is based on the experience acquired in the Biebrza Valley, and often even performed by the same people (J. Krogulec pers. comm.).

In Belarus, cutting of shrubs without biomass removal was implemented in the framework of the UNDP-ClimaEast project on in total more than 500 ha at Sporava and Zvaniec in 2015-2016. Several species of willows *Salix* spp., young birches *Betula* spp., and Black Alder *Alnus glutinosa* were cut. In the first year, a light tractor with wide double wheels and a mulcher cutting up to 10 cm thickness were used (**Fig. 4.3.2** and **4.3.3**). In the second year, on the mown area intensive regrowth especially of *Salix aurita* and *S. myrsinifolia* was observed (**Fig. 4.3.4**). Regrowth was less intensive after mulching than after cutting of the shrubs. In the second and third year, this

area was mown with a rotational mower (both herbaceous vegetation and new shrubs) and the biomass was pressed and removed as bales (**Fig. 4.3.5**). Mulching followed by mowing in the second and third year proved to be effective in limiting shrub cover and regrowth. Another important activity was to eradicate all trees (birches and alders) on the mineral islands inside the open fen area to limit diaspore distribution. Mulching was mainly implemented in summer, when the water table was very low and the impact of the heavy machinery (c. 250 g/cm^2) on soil properties was expected to be little. At Sporava, a substantial part of the mulched (but not removed) biomass was taken away during spring floods, which occur almost every year.

The ClimaEast project also tested an Anderson Biobaler, a machine that simultaneously mulches and presses bales from shrubs. This machine is the most effective in shrub removal, but can be used only at very dry parts in the periphery of a mire, as it has the weight of 7 t on two wheels. To use such machine on fen mires, it would be necessary to mount it on tracks to sub-

▲ **Fig. 4.3.2**
(left) Cover and height of shrubs before mulching, Sporava, Belarus, October 2015 (photo: M. Maximenkov).

▲ **Fig. 4.3.3**
(right) View on the Aquatic Warbler breeding site Sporava, Belarus, directly after mulching, October 2015 (photo: M. Maximenkov).

◄ **Fig. 4.3.4**
Regrowth of willows in the following year at Sporava, Belarus, 2016 (photo: M. Maximenkov).

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► **Fig. 4.3.5**
Section of the Sporava Mire that was mulched in 2015 and subsequently mown, Belarus, 2017 (photo: M. Maximenkov).

stantially reduce soil pressure. To date, machinery for cost-efficient shrub removal on wet fens is still lacking (A. Kozulin pers. comm.).

Ukraine: a well-monitored shrub removal site in Ukraine is the Vetly-Birky site (**Fig. 4.3.6**). In autumn 2012, a 25-ha area was selected, consisting of 4 ha of bushes, 8 ha of Reed vegetation, and 13 ha of low sedge vegetation. It contains a 4.2 km long Aquatic Warbler monitoring transect. On half of this area (=12 ha), eleven singing males were counted in 2011, and six males in 2012, respectively. In the winters 2012/13 and 2013/14, the bushes were cut down, and the Reed mown. Aquatic Warbler numbers on the 12 ha monitoring plot were higher in the following years: 21 (2014), 14 (2015), 17 (2016), and 17 males (2017; A. Poluda pers. comm.).

Prevention of regrowth

The removal of shrubs and trees is not sufficient by itself. Prevention of regrowth should also be adopted. This can be done in two ways: decreasing trunk and root viability, and removal of offshoots.

There are several methods of decreasing trunk and root viability, with various effectiveness and applications. Stump extraction in peatlands is normally not recommended, because it is too destructive on the peat layer. An exception is the removal of seedlings, in which case the most effective (but also the most effortful) method is uprooting. Proper timing and height of cutting are essential in reducing regrowth. In the case of Black Alder *Alnus glutinosa*, it could be the most effective to cut trees during autumn at or just below the ground surface (Kamocki et al. 2018). High water level above soil surface or frozen soil should be avoided during this action, as it could prevent correct execution. For birches, the most effective way turned out to be a winter cut at breast height (120 cm), although differences with those cut above or below ground level were not great (Kamocki et al. 2016). In any case, elimination of birch trees by applying a single cut is rather not possible and the treatment should be repeated.

While deciding on the height of cutting, the planned management in subsequent years is of uttermost importance. If machine mowing is planned, the height of the stumps is crucial, as high stumps can damage the cutting tools, especially when they are lower than the rest of the vegetation and thus not visible for the driver. Stumps of 120 cm height should be visible and could be passed without danger,

► **Fig. 4.3.6**
View of the monitoring plot in Vetly-Birky, Ukraine, before (top and middle, 2012) and after bush removal (bottom, 2014; photo: A. Poluda**).**

but would also prevent machine mowing in case of high density. Additionally, stumps infected and weakened by fungi could be broken by wind and fall into the vegetation, thus posing danger for mowing machinery. It is quite difficult and potentially the most labour-intensive to cut trees at or below ground level. Although such trunks produce more sprouts (Kamocki et al. 2016), it could be the best option in machine-mown sites. Retaining high trunks appears to be justified in areas where plant succession needs to be halted or slowed down, and it is not possible to regularly remove suckers in following years. This technique seems promising also when creating ecotone zones. A similar method is girdling (ring-barking), i.e. stripping a 20 cm high piece of bark and phloem around the circumference of the trunk at 1-1.5 m height. If this treatment is performed during the growing season, roots are cut off from nutrients transferred from leaves, which, at the same time, still take sap from roots. This leads to gradual withering of the tree and prevents appearance of suckers. The effectiveness of this method depends to a large extent on the tree species, being quite successful with birches but not with alders. Withered trees usually need to be removed later on. Another solution is milling, notching, or drilling trunks. Generally, these methods increase the area of pathogen penetration and accelerate drying. If feasible, the water table in the area of shrub removal could be raised to cover trunks, or, if floods occur naturally, shrub removal can be performed just before the expected water table rise. The effectiveness of this method depends on the duration of flooding (the longer, the better).

Another solution is the use of chemical or biological pesticides. Application of both is restricted in National Parks and Nature Reserves in Poland and requires a permission from the Ministry of Environment, unless it is included in a conservation plan or conservation action plan. Chemical pesticides could be very effective but not friendly for the environment, and can be hazardous for other plants or animals. With agricultural intensification and growing usage of pesticides, protected sites are among the few areas free from pesticides and should be kept that way. So pesticide application should be avoided if only possible. In the Biebrza National Park, it is not even considered to be used in the foreseeable future.

At present, there is no well-studied biological method that could be used to constrict regrowth of shrubs and trees on Aquatic Warbler sites. In forestry, the main such product is based on a fungus, *Phlebiopsis gigantea*, and is chiefly used in coniferous forests planted on former farmland. This fungus is used to protect the trunk from the infection of roots by bracket fungi and faster decay is a side-effect. There are other products that contain fungi feeding on deciduous wood, but to date they have not been used to suppress secondary succession on marshes. Their effectiveness is therefore unknown and would require testing before any wider application. Research aimed at finding a species of a fungus that would be best-suited for this purpose might be necessary. Generally, such biological methods are easier to use and more effective on thicker trees. If density of trees and shrubs is high and trees are thin, treatment with chemical or biological substances is difficult and their effect is weaker. Additionally, even infected birches still could produce sprouts (Kamocki et al. 2016), so the biological method could not supress their regrowth to a large extent.

In the Biebrza Valley, application of various methods of reducing the viability of roots and trunks is rather limited due to their labour-intensiveness and the large area to be treated. Hence, sucker removal is applied through mowing in successive years. It was assumed that annual mowing in the five years following bush removal should be sufficient to weaken trunks (Stoneman & Brooks 1997). It turned out that such intensive mowing is not needed at most of the Aquatic Warbler habitats in the Biebrza Valley. Trees are regrowing quite slowly, mainly because of elk grazing. Elks are rather not able to stop tree and bush encroachment but can slow it down, sometimes quite considerably. Thanks to that, mowing every two years or even more rarely is enough for sprout control in most places. Further frequency of mowing for conservation purposes should be adjusted to the risk of plant succession at a given location: the higher the risk (the more bush and tree seedlings in a year), the higher the frequency of mowing should be (every two to five, ten, or even more years).

Recommendations

Although the shrub removal machinery used today can be operated also on wet soil, one should bear in mind that there may be unwanted effects on soil and vegetation, especially if tussocks are present (Kotowski et al. 2013; Chapters 4.1 and 4.4). For this reason, in the case of extended flooding, one should consider abstaining from machine bush removal until the water level is lower again. Bush removal by hand is still allowed then, if workers would move through the peatland on foot and not by vehicle, but working conditions for people are very harsh when there is a high water level. It can be beneficial to perform bush and tree removal during winter, when no or a low snow cover is present and the soil is frozen – bearing in mind that it would not be possible to cut trees at or below the ground level then. Bush removal at sites with tussocks should be performed as rarely as possible and with minimum amount of passages, or preferably by hand.

As lignified plant parts decompose relatively slowly, great care should be taken to remove all cut plants. This is important in order to prevent further eutrophication of the managed sites, not only where species and communities dependent on nutrient-poor conditions occur, but also generally to reduce the need for high frequency mowing to maintain suitable Aquatic Warbler habitat conditions (see also Chapters 3 and 4.1). It is also a reason why usage of flail mowers with no possibility for cut biomass collection is not advisable.

Finally, a problem linked to the prevention of secondary succession is the ecotone zone. If succession affects a large area, the transition zone between open peatland and forest is typically wide. However, if bush and tree removal followed by mowing are applied in an area that is adjacent to an area where succession continues, in most cases the ecotone zone disappears and a clear-cut border between open peatland and forest is created. This is not desired, as an ecotone hosts a range of valuable species, the loss of which will reduce biodiversity. In the Biebrza Valley, this threat is prevented through the active shaping of the ecotone zone. Places where bushes are removed usually neighbour onto areas where succession is so advanced that restoring them for the Aquatic Warbler is pointless. In these locations bush thinning, the removal of higher trees and similar actions are applied. In addition, the border between mown and unmown areas should not be straight.

As habitat loss due to the abandonment of land use is one of the main current threats to the Aquatic Warbler (Chapter 3), bush removal is an important intervention measure. Bush and scrub removal is performed by hand or with machines. The use of machines is associated with problems such as pressure on the ground, which, if too high or frequent, might be detrimental to the peat layer, and biomass collection, which is crucial to prevent eutrophication and the formation of a thick litter layer. Scrub and tree removal will often require follow-up management as offshoots appear, which would usually be mowing with method and frequency adapted to specific conditions in a given place. Due to conflicting conservation priorities, it is not always optimal to remove shrubs and trees; a key has been developed to assist decision-making, and the method is modified to retain or create an ecotone zone, important for species other than the Aquatic Warbler.

4.4 Mowing

FRANZISKA TANNEBERGER

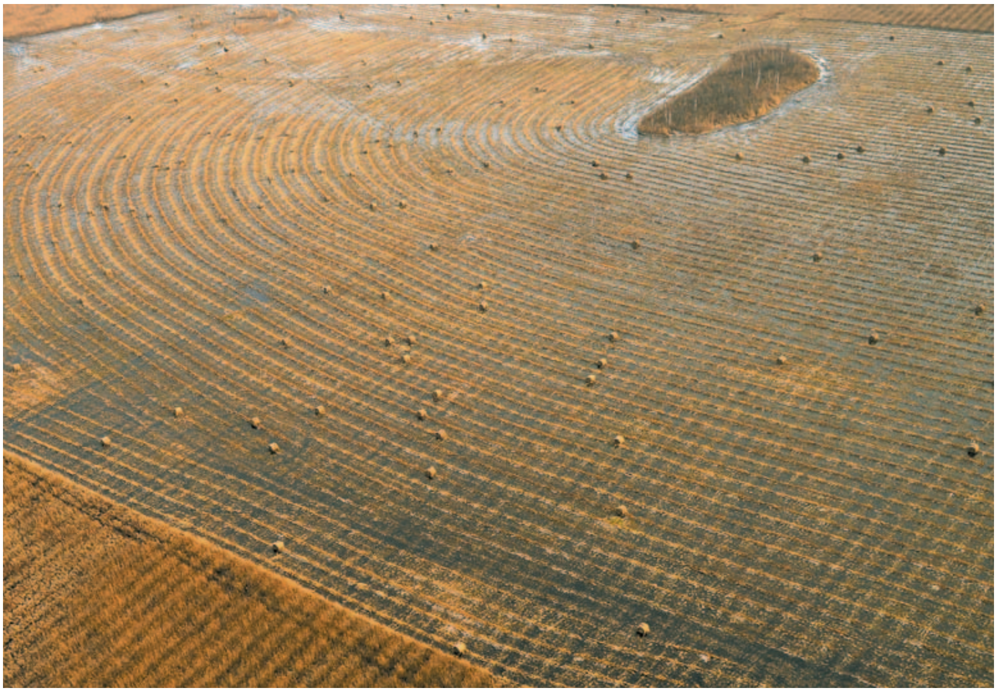
Mowing may be needed to maintain or restore the vegetation structure and composition preferred by the species during breeding (see Chapter 2.3). It can counteract successional overgrowth triggered by drainage and eutrophication (Chapter 4.1) but should be avoided in the (quite scarce) areas that have retained a natural resistance and resilience against tree encroachment, because cut trees and shrubs tend to regrow rapidly making subsequent mowing management increasingly necessary (**Box. 4.1.1**). Management of water quantity and quality is crucial to limit the need for continued mowing (Chapter 4.2). In some cases, removal of trees and shrubs (dealt with in Chapter 4.3) is needed before mowing of herbaceous plants can start. Mowing is of key importance in Aquatic Warbler habitat management, as it is well tested and proven as an effective management tool. In contrast, there is very little evidence on grazing effects in wet fens in general (Middleton et al. 2006) and in Aquatic Warbler habitats in particular (Chapter 4.5). Studies on the effectiveness of grazing versus mowing in undrained calcareous fens (Stammel et al. 2003) and in an abandoned fen meadow (Hald & Vinther 2000) showed that mowing resulted in somewhat higher species richness than grazing, and Kohler et al. (2004) found herbage removal to be the most important element of grazing in the maintenance of vegetation. Cutting and removal of biomass mimics naturally more nutrient-poor conditions and corresponding vegetation structure. As it does not, in most cases, actually restore nutrient-poor conditions or halt succession, such management needs to be continued periodically.

▼ **Fig. 4.4.1**
Traditional hay-making in northern Ukraine, June 2005 (photo: F. Tanneberger).

History of fen mowing in Aquatic Warbler breeding sites

Mowing, largely by hand scything, and the use of litter as bedding material for cattle used to be a common rural practice in fen mires over centuries (**Fig. 4.4.1**; Kotowski 2002, Joosten & Clarke 2002, Joosten & Tanneberger 2017) and created a small-scale mosaic of open vegetation (Øien & Moen 2001, Sutherland 2002, Billeter et al. 2003). This practice was completely abandoned in most European regions (more recently in central and eastern Europe, where it is still present in some places) or replaced by more intensive mowing or grazing (partly later followed by abandonment). Scything is no longer common practice in Aquatic Warbler breeding sites and is seen mainly during scything competitions in famous fen mires (such as the ones at the Biebrza National Park in Poland, at Sporava in Belarus, and at the Prypiat-Stokhid National Park in Ukraine, **Fig. 4.4.2**, see also Chapter 7). These developments, along with nitrogen and phosphorus enrichment, have led to a change in vegetation and nutrient conditions that has caused the loss of habitats of many plant and animal communities (Kotowski 2002, Hodgson et al. 2005, Wassen et al. 2005).

In the Biebrza Valley, abandonment of mowing, which to a large extent occurred at this site around the 1970s, was identified 30 years ago as being responsible for the expansion of bushes (Pałczyński 1985). An



▲ **Fig. 4.4.2**
(left) Scything competition in the Prypiat-Stokhid National Park, Ukraine, July 2014 (photo: V. Veremchuk).

▲ **Fig. 4.4.3**
(right) Purpose-built mowing machinery with very low ground pressure and fast working speed (adapted piste-basher) introduced in 2007 to the Biebrza National Park, Poland (photo: L. Lachmann).

◄ **Fig. 4.4.4**
Large-scale mowing and baling of biomass at the Ławki Mire (Biebrza Lower Basin), Biebrza National Park, Poland, December 2012 (photo: P. Świątkiewicz).

EU LIFE project implemented by the Polish Society for the Protection of Birds (OTOP) in 2005-2011 catalysed the revival of fen mowing in that location. By spring 2010, almost 2,300 ha were again under regular management. Purpose-built prototype mowing machinery with very low ground pressure and fast working speed (**Fig. 4.4.3**) became used across the site. The Biebrza National Park has made 12,500 ha of public land available for management under lease agreements that guarantee the benefit for biodiversity (Lachmann et al. 2010). A targeted Aquatic Warbler agri-environmental package provides a financial incentive for local farmers and enterprises to take up the lease and implement mowing on a large area (**Fig. 4.4.4** and Chapter 5). Based on data of 2005-2010, the effects of mowing on Aquatic Warbler density and productivity in the Bierza National Park have been analysed (**Box 4.4.1**, Oppel et al. 2013). A study on the breeding productivity of the Aquatic Warbler was conducted in the same location in 2010-2012 (Kubacka et al. 2014, **Box 2.5.2**). It explored the effect of mowing on the density of nests, fledged chicks, and singing males, in areas mown one, two, and three years earlier (low management priority), and in unmown areas (but still used for nesting and thus of medium management priority). The study demonstrated that both breeding productivity and singing male density were the lowest

4.4

Box 4.4.1
Effects of mowing on Aquatic Warbler density and productivity in the Biebrza National Park (Poland)

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With a dataset for the period 2005-2010, derived from annual full counts and the exact mapping of the location of singing Aquatic Warblers for the whole of the Ławki Mire, the core site for the species in the Biebrza Valley, the effect of mowing on densities of Aquatic Warbler males was investigated (Oppel et al. 2013). The analysis relied on a before-after control-impact (BACI) approach and a test for a multi-year effect of mowing management. The former accounted for the effects of observer and date on singing male detectability within a counted block. In the BACI approach, the mowing management was split into 'freshly mown' (i.e. mown on the preceding autumn or winter) and 'previously mown' (i.e. mown more than one year earlier). The difference in the density of singing males between managed and unmanaged units of habitat was compared before and after mowing took place in a block. For the multi-year test of mowing effects, the temporal trends in numbers of singing males obtained from full counts were compared between mown (both freshly and previously) and unmown areas. The analysis was done separately for low-, medium-, and high-priority management areas, based on the extent of plant succession. Results did not show a statistically significant effect of mowing on the numbers of Aquatic Warbler singing males, neither in freshly nor in previously mown areas in low management priority areas. A significant positive effect of mowing on the numbers of singing males was seen in previously mown areas in medium and high priority areas; however, it was due to one specific plot and year. The analysis of temporal trends indicated that while the temporal trend in Aquatic Warbler numbers did not differ between managed and unmanaged areas in low and medium management priority areas, the effect of mowing was seen in high management priority areas, such that the numbers of singing males in managed areas increased, while those in unmanaged areas did not change (**Fig. 4.4.5**). Despite the drawbacks of the full-count method due to very high random variation as a result of a single count per plot, the results did show that in patches of fen habitat that were overgrown with bushes, small trees or reeds – i.e. the high-priority management units – over time mowing indeed had a positive effect on the numbers of Aquatic Warbler males. In less overgrown patches, in turn, it did not have any effect.

Table 4.4.1

Area of hand and machine mowing on land leased to farmers in the Biebrza National Park, Poland, in 2014-2016 (P. Marczakiewicz pers. comm.).

Year	Hand mown area (ha)	Machine mown area (ha)
2014	493.20	1,740.68
2015	137.57	1,066.95
2016	107.23	1,782.81

in the season that followed mowing and peaked two years after mowing, with a gradual decrease afterwards. Importantly, the study of Kubacka et al. (2014) indicates that the habitat for the species regenerates two years after mowing and some of its features – which likely boils down to a higher invertebrate productivity and hence higher food abundance – promote high Aquatic Warbler numbers.

Recently, large areas have again been mown by hand to avoid unwanted effects of machine mowing (Kotowski et al. 2013). Within the area of the Biebrza National Park leased to farmers, more than 100 ha are mown annually by hand (**Table 4.4.1**). The exceptionally high figure for hand mowing in 2014 is due to a very wet summer with a lot of rainfall in July and machine mowing prohibited by the Park in large areas. The remaining land is probably either mown by machine or not at all, as hand mowing is more expensive than machine mowing and only done on prescribed hand mowing areas. Hand mowing is done mainly with brush cutters, which are very noisy, often even noisier than the piste-bashers, less efficient, and slower. Hand mowing areas far from roads are accessed using piste-bashers so access roads are created anyway and are even deeper, because more passages are necessary with hand mowing.

Similar late summer or autumn mowing regimes combined with use of the biomass for energy production have also been implemented in other key Aquatic Warbler breeding sites, e.g. in the Lublin area (Poland) and the Sporava Mire (Belarus, **Fig. 4.4.6**). In very few breeding sites (e.g. in Rozwarowo, Poland), winter mowing is implemented and the biomass (mainly Reed) is used as a building material for thatched roofs. Since demand for this construction material in Europe is high (Wichmann & Köbbing 2015), it opens a promising economic incentive to maintain favourable state of Aquatic Warbler habitats with high reed cover (see also **Box 5.7**).

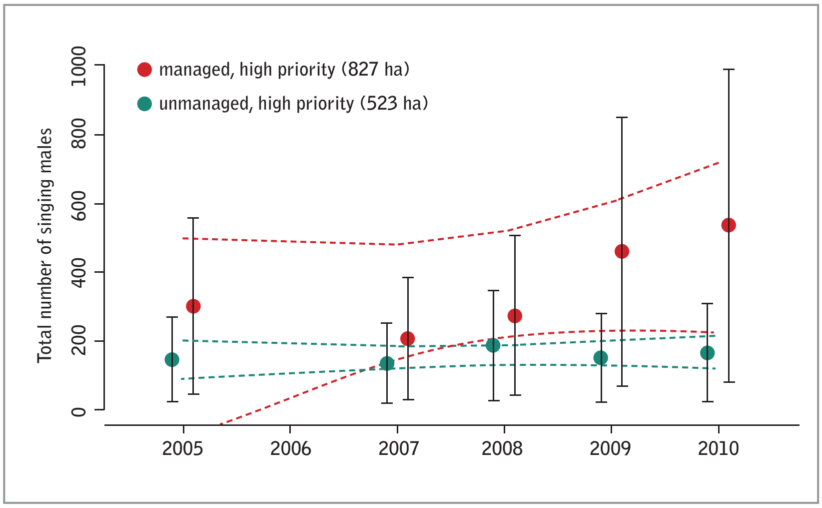
In turn, it is also clear that mowing during the breeding season in active breeding sites is detrimental for the species, through the destruction of active nests and the removal of shelter. Aquatic Warbler numbers increased in Hungary shortly after cessation of early mowing (Kovács & Végvári 1999), and decreased in Germany during a period with either early mowing of nesting sites and/or complete abandonment of mowing (Tanneberger et al. 2008). However, in strongly eutrophic sites, such as the Lower Oder Valley, early mowing is needed to counteract succession (see below).

Effects on vegetation

Mowing reduces litter, increases light availability at the ground level, and therefore enhances seedling recruitment and species performance (Kotowski et al. 2001; Jensen & Gutekunst 2003). Species such as *Viola palustris* perform better at higher light availability (Jensen & Meyer 2001; Kotowski et al 2001); however, mowing only increases species richness if the species are still part of the standing crop of the community, are in the seed bank, or can disperse to the site (Billeter et al. 2003).

Mowing also interacts with nutrient conditions. Nutrient deficiencies (mainly of N, P, or K) are typical of fen mires and nutrient ratios can indicate limitations for the total plant productivity of a site. In reality, different species have different demands, and experience the environment differently, so species composition and diversity of fen plant communities can change as nutrient levels, ionic forms, and ratios change (Rydin & Jeglum 2013). As most terrestrial ecosystems of the temperate zone, many fens are N-limited and N-enrichment is the major cause of plant species loss. For percolation fens along a climatic gradient from the Netherlands to western Siberia, including Aquatic Warbler breeding sites, Wassen et al (2005) showed that P-enrichment can be more important than N-enrichment in the loss of plant species. Long-term mowing and hay-making may lead to a reduction in N mineralisation, but cannot compensate for increased N mineralisation through severe drainage (Wassen & Olde Venterink 2006). It may also strongly alter N:P:K stoichiometry, as demonstrated by Olde Venterink et al. (2009) for P- and N-limited undrained fen sites in the upper course of river Biebrza in the Biebrza National Park.

Mowing of Reed *Phragmites australis* stands leads to denser and shorter stems (Haslam 1972, Cowie et al. 1992, Valkama et al. 2008). Mechanical damage during the period of emergence, which lasts until about July, might stimulate stem density as dormant buds are activated to replace damaged shoots. Single summer (August) mowing has been tested at the Rozwarowo Marshes (Poland) during a LIFE project and led to short-term reduction of *Phragmites* height and cover (after one year), but both parameters increased afterwards again. As



▲ **Fig. 4.4.5**
Total number of singing males in managed and unmanaged high priority management areas in the Ławki Mire in the Biebrza National Park, Poland, in 2005-2010 (from Oppel et al. 2013).

▲ **Fig. 4.4.6**
Unmown and mown parts at Sporava, Belarus, May 2007 (photo: A.Kozulin).

flooding with nutrient-rich water affected the site more strongly after summer mowing had started, it is not possible to disentangle the effects of summer mowing and eutrophication (Tanneberger et al. 2014). Early summer mowing (June) with repeated, second mowing in autumn was tested in the same LIFE project in the Peene Valley (Germany) and led to a substantial decrease in Reed height and cover (Tanneberger et al. 2012). It is, however, only feasible in sites not occupied by the Aquatic Warbler. Winter mowing above the water level is likely to maintain Reed height and cover (Güsewell et al. 2000) or even enhance vegetative expansion (Engloner 2009, Deák et al. 2015) and generative reproduction (Ostendorp 1999, Valkama et al. 2008). A reduction of Reed cover seems likely only at special mowing conditions: Studies from several German and Swiss sites (Klötzli & Züst 1973, Krisch et al. 1979, Marschalek et al. 2006, Ritterbusch et al. 2017) have shown that a mowing height under the water level leads to rapid die-off of the plants, especially when combined with frost. Herbicides can be effective in stopping the expansion of Reed (e.g. Axell 1982 for the Minsmere Reserve, UK, and Derr 2008 for wetlands in the USA) but should be generally not used in groundwater-related systems such as fen peatlands. This applies in particular to substances such as glyphosate, which have been shown to be toxic e.g. for amphibians (Wagner et al. 2013). Overgrowth by Reed in a fen mire reflects hydrological and hydrochemical disturbance and should be, first of all, tackled by improving water management (Chapter 4.2).

Timing and frequency of mowing for Aquatic Warbler conservation

When planning or recommending mowing, it is important to distinguish between restoration and maintenance management (Chapter 4.1). Maintenance management is implemented in currently occupied Aquatic Warbler habitat and aims to maintain suitable conditions, while restoration management is implemented in potential habitat that is not currently occupied, with the aim to restore its suitability for the species. The required action may differ in important points. The timing and frequency of mowing necessary to maintain or restore Aquatic Warbler habitats depends primarily on the extent of plant succession of a site (Budka et al. 2013), determined primarily by its nutrient conditions (see Chapter 4.1; Tanneberger 2008). With increased supply of a limiting nutrient, e.g. by N deposition large productive sedges and grasses will increase their dominance and bryophytes and other low-growing species will decline (Rydin & Jeglum 2013).

In practice, the proximate cause of mowing is not the trophic level but advancement of succession, and the amount of Reed, trees, and bushes can be used as an indicator on how often and when to mow Aquatic Warbler habitats:

- in mesotrophic sites without signs of overgrowth with shrubs or Reed (e.g. central parts of the Ławki Mire, Poland, and Udai, Ukraine): vegetation management is not needed at all;
- in other mesotrophic sites: late mowing every two years in sites prone to succession by shrubs and Reed, and every four or more years (up to 20 years) in sites with slow succession is sufficient; observation of potential vegetation succession should give indications of the optimal mowing frequency for each site;
- in eutrophic, moderately rich or mesotrophic sites without Aquatic Warblers (habitat restoration): late mowing, but in case of Reed overgrowth early summer mowing between end of June and mid-July for a number of years;
- in eutrophic, moderately rich and mesotrophic sites with Aquatic Warblers (habitat maintenance): late mowing after the breeding season (starting between 15 August and 30 September, depending on the site);
- in eutrophic, rich sites without Aquatic Warblers (habitat restoration): early summer mowing (before 31 July);
- in eutrophic, rich sites with Aquatic Warblers (habitat maintenance): early

summer mowing (before 31 July) with nest protection (search for breeding females necessary!) and late mowing after breeding season (from 15/30 August) in nesting sites creating a mosaic ('alternating land use'; **Box 4.4.2** and **Fig. 4.4.7**).

Ideally, mowing in breeding sites should only take place after the last broods are finished. The timing of late broods differs between sites and from year to year (see Chapter 2.5). After 15 August there is only a very small chance of destroying the last remaining active broods, while by 15 September the breeding season has fully ended (Kubacka et al. 2014). When there is the need to find a compromise with farmers, it may be also considered to start mowing in the first half of August. In eutrophic, rich sites, nesting sites must be protected from mowing before August but a part of the area should be mown before August to maintain suitable breeding conditions (alternating mowing, see **Box 4.4.2**). Mowing should be finished by the end of February/March, leaving enough time for vegetation development in spring before the birds' arrival.

In order to prevent the build-up of dense litter layers and to extract nutrients, biomass should normally be collected and removed from sites after mowing. This is less crucial in sites with lower nutrient levels, and therefore longer periods between mowing (3-5 years or more), lower annual production of biomass, and higher water levels. Especially at sites with strong water level fluctuations and thus fast decomposition of litter, as shown for the Peene Valley in Germany, there is little litter accumulation (Völlm & Tanneberger 2014). Here, especially if the removal of biomass is technically and financially challenging, it can be acceptable or even beneficial to leave all or part of the biomass on site in some years.

Observing the correct mowing frequency is especially important as the modern heavy machines used for mowing, such as adapted piste-bashers (see below) could affect plant composition of the fen mire. In the Biebrza National Park (Poland) Kotowski et al. (2013) demonstrated that piste-bashers caused a decrease of those plant and moss species that are likely to create a microhabitat for other species by providing shelters above groundwater level (hummock mosses, tussock sedges, and shrubs), and an increase of forbs (non-grass plants). This simplified the structure of the fen and reduced the amount of sedges

Box 4.4.2

Alternating mowing in strongly eutrophic sites

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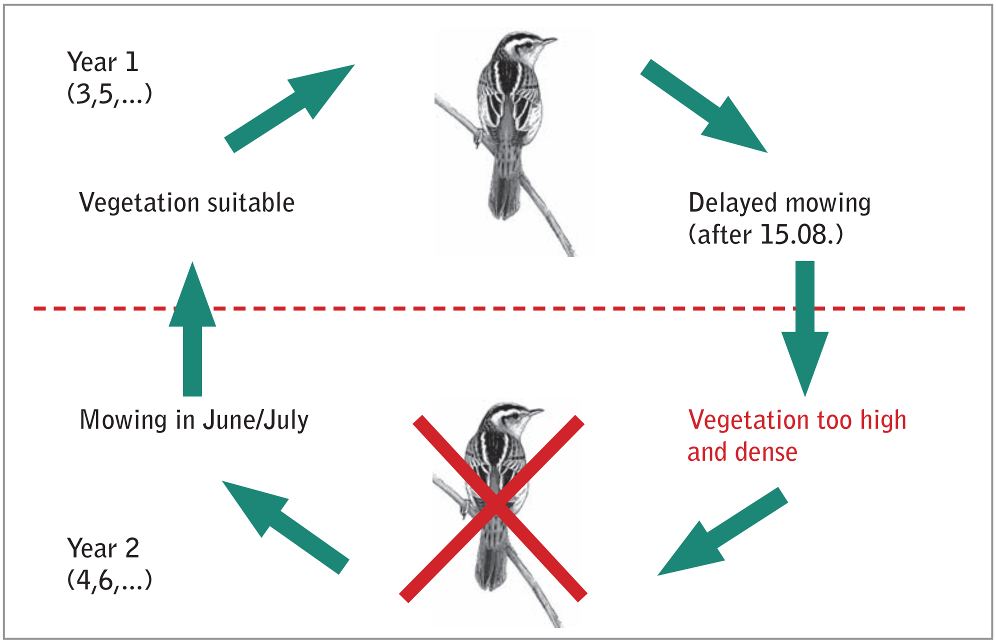
Although effective in preventing overgrowth with bushes or Reed, permanent late mowing proved to be an inappropriate management method for Aquatic Warbler habitats under strongly eutrophic conditions and with artificial drainage early in the breeding season, e.g. in the Lower Oder Valley in Germany and in the Nemunas Delta, Lithuania (Tanneberger et al. 2008). In the Lower Oder Valley National Park in 1993-2006, mean vegetation height increased from 0.9 to 1.26 m (**Fig. 4.4.8**, upper panels), while the cover of herbs decreased from 8.5% to 0.7% in sites that became abandoned by Aquatic Warblers in 1998. Here, land use intensity gradually decreased: the sites were mown in June or July in 1992-1994 and subsequently between the end of August to early September until the complete abandonment of land use in 2001. In sites occupied by Aquatic Warblers and with continuing early land use during the study period (before the end of July), no significant changes in the vegetation height and composition could be observed (**Fig. 4.4.8**, lower panels). The reintroduction of early mowing in abandoned fen meadows led to an increase of plant species, especially small- and medium-sized herbs, from three to 16 within six years (Pfadenhauer et al. 2001). Unfortunately, early mowing is also a serious threat to breeding birds and without additional nest protection the early mown areas might act as an ecological trap (Battin 2004) for the birds.

Based on the experience in the Lower Oder Valley National Park (Tanneberger et al. 2008), in order to revert the changes in vegetation caused by late or no mowing, detrimental to Aquatic Warbler habitats, an alternating management with late mowing in years when Aquatic Warblers are present and earlier mowing in the absence of Aquatic Warblers is recommended in strongly eutrophic sites (**Fig. 4.4.7**). In such sites, any static management with a single fixed timing of land use is impractical or even detrimental. Instead, sound bird monitoring is needed and flexible management decisions have to be taken each year according to the occurrence of the target species (Bellebaum & Tanneberger 2018). Such management would also approach the form of land use that originally led to the development of these habitats: before the areas were drained, the extent and timing of mowing was mainly dependent on the strongly variable spring water tables.

4.4

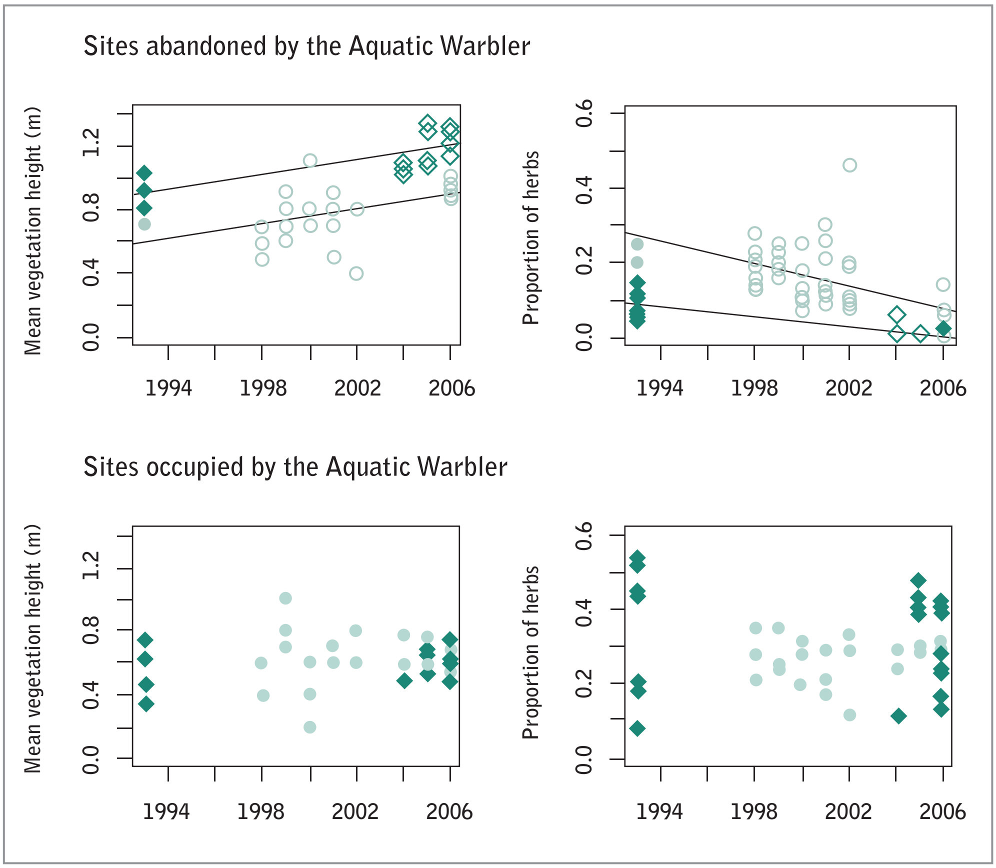
► **Fig. 4.4.7**

Proposed alternating land use in eutrophic, rich Aquatic Warbler breeding sites (from Tanneberger 2008).



▼ **Fig. 4.4.8**

Mean vegetation height and cover of herbs in July 1993–2006 on Lower Oder Valley sites which became abandoned by Aquatic Warblers during the study period (upper panels, circles = long-term study plot margin, diamonds = long-term study plot centre) and on sites which were occupied by Aquatic Warblers throughout the study period (lower panels, circles = southern polder, diamonds = central polder). Filled symbols indicate occurrence during or up to three years after the study year. Changed after Tanneberger et al. (2008).



and sedge tussocks, which are crucial for Aquatic Warbler nesting (see Chapter 2.5). On the other hand, this study is by no means conclusive, since it only included plots mown one or two years earlier and did not differentiate between them. With time after the mowing event, the structure of the fen regenerates to some extent (Abramchuk 2015). Concerns have recently also arosen because the tracked mowers may cause eutrophication (Banaszuk et al. 2016). In response, lowering frequency of mowing to once in 5 years or, where feasible, use of hand-operated machinery was recommended.

Also the water table should be taken into account. In the Chełm Marshes (southeastern Poland), which feature a broad range of water levels, it was shown (Kubacka et al. in prep.) that in high water levels, mowing does not improve but destroy Aquatic Warbler breeding habitat due to excessive reduction of vegetation height, while in areas with low water table it has similar effects as found for the Biebrza Valley. Therefore, the decision on mowing frequency (and techniques) should be informed by weighing potential costs and benefits. This approach has been adopted in the current Aquatic Warbler management plan for the Biebrza National Park (Budka et al. 2013).

Types of mowing machinery and mowing techniques

Various types of mowing and cutting machinery are suitable for use on fens. Hand tools or small machines can be ideal for small, isolated sites, but are neither cost-effective nor viable on large areas. Apart from the traditional scythe (**Fig. 4.4.2**), small hand-operated mowers and pedestrian-driven mowers with reciprocating blades (**Fig. 4.4.9**; recently also available in remote controlled versions) are used.

The main challenge in fen management is notoriously not the cutting but the gathering and removal of cut material from sites (McBride et al. 2010). Recent mechanical developments, such as the adapted piste-basher ('ratrak') used in Poland have revolutionised fen management. The main mature technical solutions for harvesting and processing of unspecific biomass on large wet peatlands are (Wichtmann & Tanneberger 2009, Wichmann et al. 2016):

- tracked special machinery: crawler-mounted vehicles from companies such as Mera-Rabler or Meili and converted piste-bashers from manufacturers such as Kässbohrer (**Fig. 4.4.3**), Wildemann, Ratrac, or Leitner, the latter usually individually optimised stand-alone solutions (Rechberger 2003) but also used in the peat industry, bunker silo making, and landfill remediation; they have large bearing surfaces and their weight is distributed very well to the ground, but they can cause damage to the vegetation by narrow manoeuvres, are not roadworthy, and are transported via flat-bed trailers;
- wheeled special machinery: mostly Seiga machines (light vehicles with two or three axles and with low pressure balloon tyres built by the Danish 'Seiga' company, **Fig. 4.4.10**, no longer produced but still constructed by several small companies); with limited engine performance, able to swim but hard to manoeuvre, damage may be caused by slippage;

▲ **Fig. 4.4.9**
Brielmaier mower at the Landgraben Valley, Northeast-Germany, August 2011 (photo: K. Vegelin).

4.4

▲ **Fig. 4.4.10**
Seiga harvester used for testing summer mowing at the Rozwarowo Marshes, Poland July 2007 (photo: F. Tanneberger).

▲ **Fig. 4.4.11**
Light tractor (850 kg) used for mowing a 120 ha site annually in the period 2006-2017 in the Peene Valley, Germany, September 2009 (photo: F. Tanneberger).

- light tractors: mostly with cutter bar, usually only for mowing, occasionally for biomass removal (small HD bales), have low performance and high costs in relation to area, suitable only for small scale applications, least problematic for the peat soil (**Fig. 4.4.11**);
- adapted conventional agricultural machinery: farm tractor with flotation wheels or twin types with a light baler on a tandem axle, alternatively with bogie or delta tracks, used in moderately wet areas, under dry conditions or frost, with high mowing performance but application limited by high water levels and weather conditions.

The carrying capacity of peatlands is determined by the humidity of the soil (i.e. the ground water level) and the cover of vegetation (plant species, density of the sod). After Prochnow (2001), the trafficability of peatlands is not a technical but rather an economic problem: very light and specially equipped machinery adapted to harvesting wet sites without damaging the soil and tussocks is available, but is usually associated with high costs. Wiedow et al. (2016) compared the impact of harvesting machinery on wet peat soils in the Lower Peene Valley: compared to a control, there was no evidence of impact caused by the light tractor. In contrast, the impact of the snow groomer and Seiga reed harvester was very pronounced. Although these vehicles did not cause any visible damage, the decrease in shear strength showed that crossing the area influenced the sward. Driving across the area with the snow groomer further led to an increased soil penetration resistance, indicating compaction of the upper peat layer. Multiple crossings should therefore be avoided. A comparison of a larger set of sites mown by light tractors and tracked machinery, respectively, in Northeast-Germany suggests low topsoil but continued compaction over the entire 80 cm depth profile for the light tractor, and strong topsoil but less pronounced deeper compaction for the snow groomer (F. Närmann pers. comm.).

In addition to using site-adapted machinery with low ground pressure, it may be necessary to fortify frequently used paths, access and biomass loading points e.g. using the so-called fascine tracks made from bundles of woody branches, or to avoid structural damage to the peat soil. Such facilities are in use, for example, in the Biebrza National Park (**Fig. 4.4.12**).

Different mowing techniques are possible, e.g. the immediate mulching and collection of the still moist biomass in one go, or the cutting of high vegetation and then leaving it on site to dry and be baled and collected later (**Table 4.4.2**). The first technique, especially if implemented in summer, may possibly have detrimental effects on small invertebrate or vertebrate fauna, which may have little chance to escape after mowing, while the second option requires driving three times over the delicate peat soil. As each technique has its specific advantages and disadvantages, affecting different elements of the environment in different ways, it is recommended to use a wider variety of techniques, mowing dates spread out over the whole season (i.e. not all mowing to be done only in August and September), and smaller management units (i.e. to use one technique within a very short period only in areas not larger than 20-50 ha). This way, it can be ensured that species of invertebrates cannot by chance be eradicated from the whole site without the chance to re-inhabit areas where their population may have been affected by a particular mowing technique.

At least in some habitat types, the Aquatic Warbler prefers edges between mown and unmown areas for singing and foraging, as shown by Tanneberger et al. (2013) for the Pomeranian breeding sites. Here, mowing should aim at creating such edges by varying mowing dates or leaving strips of land unmown. Unmown patches are probably also beneficial for arthropod abundance and thus potential Aquatic War-

▲ **Fig. 4.4.12**
Crosswise arranged fascines from bushes can stabilise frequently used tracks, Biebrza Valley, Poland, September 2009 (photo: L. Lachmann).

▼ **Table 4.4.2**
Harvest methods for herbaceous biomass from wet peatlands (from Wichmann et al. 2016).

Method	Product	Method description	Practiced in (examples)	Harvest time	Biomass moisture
Harvest in one working step	Chopped biomass	harvest and transport in mounted container in attached trailer on tracks	PL, BY, LT, DE, GB, NL	summer/ autumn winter	fresh dry
	Bales	harvester with cutter bar, mounted baler for round bales and bale transport by harvester or trailer	AT, FI, CH	winter	dry
	Bundles	harvest of reed or cattail tied into bundles for thatch, transport with harvester	NL, DE, DK, PL, AT, HU, RO	winter	dry
Harvest in two working steps	Chopped biomass	1st step: mowing and biomass deposition in swaths, 2nd step: uptake, chopping, and transfer to container or trailer, biomass removal (**Fig. 4.4.13**)	DE, PL, NL	summer/ autumn winter	partially wilted/ dry dry
	Chopped biomass/long culms	1st step: mowing and deposition in swaths, 2nd step: uptake by trailers and biomass removal	DE, NL	summer/ autumn winter	partially wilted/ dry dry
Harvest in three working steps	Bales	1st step: mowing and biomass deposition in swaths, 2nd step: biomass uptake and baling with attached baler in twin tyres or tracks, 3rd step: removal of bales individually or by a tracked trailer with a loading crane	DE, NL	summer/ autumn winter	partially wilted/ dry dry

▲ **Fig. 4.4.13** **Uptake, chopping, and removal of the biomass with chopper and trailer, Peene Valley, Germany, August 2011** (photo: C. Schröder).

bler food supply, and they provide nest building material. Both the effect of edges and of unmown strips should be tested further.

In sites with a high or strongly fluctuating water level during the breeding season, the Aquatic Warbler requires tussocks for nesting. If the water level during breeding season is low, females will build a nest on the ground or in low vegetation. But if the water level is high, or at least high in some years, then the presence of tussocks is beneficial, because it provides the birds with the possibility to locate their nest above the water in a stable place. Mowing, even by hand, has always limited the size of tussocks, mainly through the removal of fresh growth and litter, but also through trampling and driving on. At least on wet sites or those with fluctuating water levels (like the Biebrza Valley), mowing should not destroy the tussocks, as they are necessary for successful breeding (**Fig. 4.4.14**). Therefore, unsuitable machinery like normal tractors must be forbidden at such sites. Any machinery used needs to have a low ground pressure, preferably less than 50g/cm² (which is less than a human foot) and wide caterpillars to drive on top of the tussocks. In addition, tussocks must not be cut off by mowing – it is important that vegetation is cut above the tops of the tussocks.

Effects on other fauna

All mowing techniques cut to a uniform height, which reduces variability within the vegetation, and can result in loss of associated flora and fauna. This may be a particular problem for invertebrates (McBride et al. 2010). Also, the way of removing the cut biomass may pose a serious threat, especially to amphibians, invertebrates, and small mammals. Such possible effects are outlined below. However, despite such potential negative effects, in many cases any mowing is better than leaving a site abandoned, and, thanks to various technical adaptations and increasing knowledge in conservation biology, potential negative effects can be minimised. Different mowing times, frequency, and equipment will affect the fauna differently. Here, we concentrate on mowing equipment. Generally, setting up mown and unmown areas as a mosaic seems particularly promising to realise positive effects and mitigate negative ones (cf. Schmidt et al. 2008).

Major references on the effects on amphibians are Claßen et al. (1996) and Oppermann & Claßen (1998), who carried out experiments with single/double blade cutter bar mowers and rotary mowers in 1995/1996 in northeastern Poland. Here, on plots mown with scythes or cutter bar mowers only 1% of the recorded amphibians were dead, whereas on plots mown with rotary mowers it was 10%. Total loss (dead and injured animals) was almost three times higher after mowing with rotary (disc and drum) mowers (27%) compared to cutter bar mowers (10%), and the degree of injury resulting from rotary mowers was much more serious than that from cutter bar mowers. Considering that amphibians do not reach sexual maturity until their third year and that they consequently may have to face several mowing events before reproduction, they call for a compulsory use of cutter bar mowers in conservation schemes.

The effects of cutter bar and rotary mowers on invertebrates (carabid beetles Carabidae and grasshoppers Orthoptera) in wet meadows were studied by Claßen et al. (1993). They concluded that invertebrates from both groups are capable of hiding themselves in the soil or escaping from mowing machines (possibly alarmed by soil vibrations). However, they expected a higher mortality in diurnal carabids and in the heavier grasshopper females and, generally, in the case of fast moving mowing machines. A suction mower also clearly enhances mortality. Humbert et al. (2010) observed surviving rates of grasshoppers of 32% when meadows were mown with rotary mowers without a conditioner crushing the plants immediately after mowing and of only 18% when mown with rotary mowers with conditioner. Effects of suction mowers on invertebrates were studied by Hemmann et al. (1987) and Großkopf (1988) on road verges. The first study demonstrated that 1) the degree of damage increases from the cutter bar mower, through the suction rotating mulcher (sucking the biomass immediately up without affecting the soil surface) to the rotating mulcher (affecting also the soil surface), and 2) the insects on the vegetation are more damaged than those on the ground. The latter confirmed the strong effect of suction rotating mulchers and indicated that areas of high importance for lots of carabids should never be treated by such equipment. Generally, although some piste-bashers in eastern Poland work with suction of biomass, this machinery seems to be much safer compared to the machines mentioned above, since the cutting height is much higher than on a normal grassland (15-20 cm above the top of tussocks) and since no vegetation or animals would be sucked directly from the site. (The suction is too weak for this, instead the rotating mower throws the biomass up into the pipe, and only once the biomass is there it could get caught by the suction).

Handke & Schreiber (1985) showed also that moles and common voles were killed by shredding. Results from Oppermann & Krismann (2002) indicate that rotary mowers killed twice as many small mammals as did cutter bar mowers, but their data were not analysed statistically due to the small sample size.

In any cases of site management where negative effects on other fauna may occur, it is recommended:

- to prepare an inventory of wildlife inhabiting the areas mown by such equipment (with particular focus on specially protected groups/species and on annual life cycles) and to monitor how species/groups develop;
- to either use such machinery only in late autumn or winter (with the additional benefit that winter mown biomass has a lower moisture content which is desired for briquetting) or to modify the equipment to a cutter bar device without a suction unit, which should be safe to use in late summer;
- to cut the vegetation at a greater height, e.g. 15-20 cm above the top of tussocks;
- to leave stripes of vegetation uncut ('invertebrate windows');
- on large sites, to reduce as far as possible the area of plots managed in one go at the same time with the same equipment, in order to create a mosaic of areas mown at different dates, and possibly with different machinery;
- to reduce the management frequency as much as possible, to a minimum that is sufficient to prevent the negative effects of succession.

▼ **Fig. 4.4.14**
Tussock cut off during mowing in the Biebrza Valley, Poland, June 2008 (photo: L. Lachmann).

4.5 Grazing

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► **Fig. 4.5.1** **Grazing in Aquatic Warbler habitat on Schmidt-Bülten, Germany, June 1988** (photo: D. Sellin).

► **Fig. 4.5.2** **Grazing in Aquatic Warbler habitat in the Świna Delta, Poland, June 1989** (photo: D. Sellin).

Similarly to mowing, grazing can reverse the successional process and suppress (though not prevent) scrub encroachment. However, grazing and mowing not only represent different management methods on open grasslands, but they usually also produce different types and structures of vegetation. Most Aquatic Warbler breeding sites are currently managed by mowing and probably have been so for a long time. As a consequence, grazing is less well tested and proven as an effective management tool for Aquatic Warbler sites. Generally, there is very little evidence on grazing effects in wet fens (Middleton et al. 2006). Still, it may be possible to maintain or even restore a favourable vegetation structure through carefully directed extensive grazing. The advantages of this method are the relatively low ongoing management costs and the potential economic sustainability. The difficulty is that a fine control of grazing densities, dates, and areas is required; also, grazing may be less feasible in large sites due to the enormous numbers of animals and the amount of grazing infrastructure needed.

Past and present examples of grazed Aquatic Warbler breeding sites

Several sites along the Polish and German coast around the Oder/Odra Estuary (**Table 4.5.1**, **Fig. 4.5.1** and **4.5.2**) are known to have become suitable when intensive grazing was replaced with low intensity grazing by cattle (mainly heifers) in the 1970s (Holz et al. 1983, Sellin 1989a, 1990). Aquatic Warbler numbers strongly decreased or disappeared when grazing was either completely abandoned (e.g. Schadefähre island, Germany, and islands in the Świna Delta, Poland) or strongly intensified again (e.g. Freesendorfer Wiesen, Germany).

On the islands in the Świna Delta, the Aquatic Warbler occurred when the sites were extensively grazed (**Table 4.5.1**; Sellin 1990). Numbers in this site decreased strongly after cessation of grazing, which allowed an increased dominance, height, and density of Reed. Since 2007, extensive grazing with additional mowing has been performed on 360 ha of islands in the Świna Delta within the Wolin National Park. Grazing was introduced as part of the LIFE Project 'Conserving *Acrocephalus paludicola* in Poland and Germany'. Grazing can contribute to habitat restoration, but in the long-term management to keep proper Aquatic Warbler habitat the recommended way is regular mowing. Since then, signs have been that this type of management creates a vegetation structure with low and sparse Reed stands, potentially suitable for the species. However, the numbers of the Aquatic Warbler in this site appear to be slowly but steadily declining, from 18 s.m. (singing males) in 2005 to 1-3 s.m. since 2013 (OTOP 2013, M. Dylawerski pers. comm.).

Freesendorfer Wiesen once hosted up to 30 s.m. (in 1988), but became abandoned by Aquatic Warblers in 1998 following an increase in cattle grazing intensity from 1995/1996 to year-round grazing by more than 6 livestock units (LU) per hectare (D. Sellin pers. comm.).

Throughout the breeding range, only a few breeding sites in the Hortobágy National Park (Hungary), Ukraine, Lithuania, eastern Poland, and Pomerania provide recent examples of breeding sites regularly grazed at low intensity (**Table 4.5.1**). It seems that only a few sites, mainly coastal or inland salt grassland such as Hortobágy and the Pomeranian coast are well suited for grazing management. Salt grassland vegetation benefits from grazing with limited intensity, including the effect of trampling and creating micro-habitats (Reise 1998), as do most wader species. Peat accumulation in coastal transgression mires (such as many coastal Pomeranian Aquatic Warbler breeding sites; Succow 2001) is also dependent on grazing since the compaction of the peat by trampling sustains the peat layer. Grazing appears to be a management tool particularly relevant for small sites. On other sites, grazing may only be the less preferred option compared with mowing, or only suitable to supplement mowing (e.g. in the Lower Oder Valley and the Warta Mouth National Park).

Generally, brackish conditions may increase the success of low-intensity grazing because Reed already grows rather low and sparse compared to more productive freshwater sites, where grazing is less likely to be sufficient. In intact or restored fen mires, water tables may be too high to allow regular grazing (i.e. above 30 cm below soil surface), and especially under eutrophic

▼ Table 4.5.1
Use of grazing in selected Aquatic Warbler breeding sites.

Site name	Grazed area (ha)	Period when grazing was applied	Type of grazing	Stocking density (LU/ha)	Aquatic Warbler number (s.m.) and trend in corresponding period	References
Schadefähre island, Germany	up to 94	until 1965	cattle (heifers)	c. 0.5-1	at least 1, trend unknown	Heise (1977)
		c. 1966-1974	cattle (heifers)	variable at low densities	up to 20, trend unknown	Bellebaum & Tanneberger (2011)
Freesendorfer Wiesen, Germany	55	1978-1989	cattle (heifers)	1-2	up to 30, trend unknown	Sellin (1989)
Islands in Świna Delta, Poland	c. 360	until c. 1990	cattle, horses, sheep	<0.5, exceptionally higher	up to 56, trend unknown	Sellin (1990)
		since 2007	meat cattle	c. 0.5, additional mowing	up to 7, stable	L. Lachmann pers. comm.
Karsiborska Kępa, Poland	50	since 2010	Konik horses	c. 0.2, additional mowing	declined from 9 in 2010 to 0 in 2013	OTOP
Mścichy (Biebrza Valley), Poland	420	since 2004	milk cattle	c. 0.1, additional mowing	c. 50, stable	OTOP
Prypiat-Tsyr, Ukraine	200	~2011	cattle and horses	>2	no data	A. Poluda pers. comm.
Uostadvaris, Lithuania	c. 60	since 2004	cattle	0.5-1.0, additional mowing	up to 4, fluctuating	Z. Preiksa pers. comm.
Sausgalviai, Lithuania	50	2006	cattle	>2, additional mowing	up to 9	Z. Preiksa pers. comm.
Šyša, Lithuania	40	since ~ 2010	cattle	1.0-1.5, additional mowing	up to 4	Z. Preiksa pers. comm.
Minija Oxbow, Lithuania	50	since 2004	cattle	0.5-1.0, additional mowing	declined from 15 in 1995 to 0 in 2006, since 2014 stabilised at ~5	Z. Preiksa pers. comm.
Alka, Lithuania	80	since 2014	cattle	0.5-1.0, additional mowing	fluctuating; 16 in 2014, 8 in 2016	Z. Preiksa pers. comm.
Hortobágy, Hungary	80	2004-2010	cattle	c. 0.5-1	c. 20, decreasing	Z. Végvári, pers. comm.

conditions like in the Lower Oder Valley, cattle grazing after the breeding season is often insufficient to remove dense sedge or reed stands without completely destroying the intended habitat structure (Bokdam et al. 2002). Besides additional mowing, water buffaloes might be a promising alternative, but have not yet been used in Aquatic Warbler habitats.

At the Lithuanian coast, there are five Aquatic Warbler breeding sites with current grazing management (**Table 4.5.1**). A negative impact (at least not positive for sure) of grazing in most of the Lithuanian sites is assumed: in the Alka Polder, Aquatic Warbler numbers are decreasing in grazed areas; in the Uostadvaris Polder (**Fig. 4.5.3**) there are only 1-2 males in recent years; near Kniaupas Bay and Kroku Lanka Lake the species has disappeared (and very intensive grazing is ongoing); and in the Šyša Polder Aquatic Warbler numbers are not increasing in grazed areas. From the Lithuanian experience, it is concluded that grazing can be positive only in peatlands with high-tussock sedges, but not in fertile flooded meadows. If grazing is introduced, all patches of sedges have to be fenced against cattle. But it is quite difficult to implement, as we can see in Uostadvaris. Of course, grazing is good for waders, but also, only on meadows with lower vegetation. Anyway, mowing is necessary after grazing (maybe not necessary every year).

In the Biebrza Valley in Northeast-Poland, Aquatic Warbler habitat was grazed up to the 1980s in the Ławki Mire and has continued today only near the village of Mścichy in the buffer zone of the Biebrza National Park. Here, the basic management for maintaining Aquatic Warbler habitat is mowing, but 'accidental grazing' by cows going to and returning from other farmers' pastures occurs (see **Table 4.5.1**). To avoid conflict with those farmers and problems with the paying agency, OTOP BirdLife Poland (who manage the site) decided to use here the mixed mowing and grazing agri-environmental packages. But this is the pragmatic solution and was not introduced purposefully for Aquatic Warbler habitat management (Ł. Mucha pers. comm.).

The only grazed Aquatic Warbler breeding site in Ukraine is Birky. Here, some 1,000 cows and horses graze on an area of 200-250 ha (**Fig. 4.5.4**). At high water levels in the floodplain, this area is reduced almost twofold. The grazed area is also used by the Aquatic Warbler, but not when the water level is low and animals trample the sedge biotopes (for example in the years 2014-2017). As a result of grazing, these sites are dominated by *Juncus* spp. (e.g. *Juncus effusus*).

While mowing or burning during the breeding season will destroy all nests and broods, less damage is expected from low-intensity grazing. Thus, under certain conditions it can reduce vegetation height and

▼ **Fig. 4.5.3**
Hereford cattle grazing in Uostadvaris, Lithuania, June 2012 (photo: Z. Preiksa).

▼ **Fig. 4.5.4**
Pasture with cows (and ornithologists) near Birky, Ukraine, 2016 (photo: A. Poluda).

density and create improved feeding habitat at a time when other tools are unavailable. In combination with mowing after the breeding season, this is a promising management method for sites occupied by the Aquatic Warbler, which would still benefit from further reduction of Reed dominance through vegetation removal in the Reed growing period. It is therefore an option that combines maintenance management and restoration management, while at the same time not destroying active nests or feeding habitat. This type of combined management has been tested on Karsiborska Kępa and the neighbouring islands of the Świna Delta in Poland, and parts of the site proved to have suitable habitat (Tanneberger et al. 2014). To be effective, cattle densities and grazing management will need to be adjusted to local conditions and Aquatic Warbler occurrence.

Overall, one should bear in mind that the Aquatic Warbler habitats subject to grazing nowadays hold very small subpopulations. These subpopulations are prone to extinction due to stochastic events, such as floods or droughts, and are typically isolated from core subpopulations, thus not receiving constant influx of individuals. This clearly distorts the potentially positive effects of grazing on habitat quality.

Aquatic Warbler-friendly grazing management

Grazing as a management tool for Aquatic Warbler habitat should be considered

- where the Aquatic Warbler occurred when the site was grazed, and its numbers have decreased when grazing was abandoned or intensified;
- where there is no history of mowing, or where mowing is difficult, e.g. because of the lack of machinery access;
- where introduction of grazing to inhibit succession is feasible considering vegetation productivity and area size;
- where selective removal of vegetation has been identified as the most appropriate form of management to achieve a diverse vegetation in terms of structure and species composition;
- where, in currently occupied sites, early vegetation reduction in addition to mowing outside the breeding season is desirable.

Both benefits and potentially less desirable consequences must be considered before introducing grazing. Animals will not graze all parts of a fen equally if they are free to roam widely. Other practices, such as cutting, mowing, and scrub management may therefore be required to complement grazing (McBride et al. 2010).

The following factors are the most important in deciding whether grazing is feasible in a particular site (McBride et al. 2010):

- Ground stability is fundamental, especially in the case of fens where heavy cattle may damage the soil and the grass sward.
- Flooding and availability of dry land: in sites prone to rapid flooding grazing is only feasible if there are either areas of raised ground available or sufficient resources to check stock frequently, and to move them quickly to another safe site as and when required.
- Meeting the health and welfare requirements of grazing livestock is essential. Herds should be checked daily.

Aquatic Warbler-friendly grazing management can be done by cattle or horses, preferably with light-weight and low-maintenance traditional breeds, since those tend to be better suited to harsh conditions. Cattle are ideal for removing long, coarse grass but less so for removing sedges. At low to medium stocking density, cattle-grazing results in a comparatively long tussocky sward of relatively uniform height, which favours a rich flora and many invertebrates. Cattle are also very useful in trampling low scrub, and breaking up mats of dead litter. However, cattle spend up to 16 hours a day resting while they digest their food, congregating on dry land or in a shelter. Animals usually have to be removed from the site in winter when water tables rise. They should also be removed when the site does not offer sufficient forage to avoid dung accumulation and soil damage around supplementary feeding sites (McBride et al. 2010).

Horses in general are more selective grazers than cattle. Grazed extensively (i.e. at low stocking densities), horses create a mosaic of shortly grazed and taller, undisturbed vegetation. This structural diversity benefits a range of species, including, for example, invertebrates, small mammals, and birds of prey. The small and hardy traditional breed of Polish Konik horses (**Fig. 4.5.5**) are known to cope particularly well with grazing on wet areas with a high density of reeds. Experience from the RSPB's Minsmere Nature Reserve in the UK (A. Needle pers. comm.) and from several sites in Poland shows that Koniks do not suffer from grazing in wet conditions, which they often choose to do, as long as they have dry areas to retreat to, and that they can be kept with minimal welfare and management measures.

Current practitioners' experience appears to be that both cattle and horses (especially Konik horses) are equally able to effectively graze wetland vegetation including areas with dominant Reed stands, and both will prefer other grazing areas if available to them. This means that some form of fencing is required to ensure grazing takes place where required.

Grazing densities should be adapted to the productivity of the site, usually between 0.3 and 1.0 LU per ha (Mc Bride et al. 2010, Rößling 2010, L. Lachmann pers. comm.). It also needs to be considered whether grazing is to be the sole vegetation management measure or whether it will be implemented in combination with mowing. In the first case, stocking densities need to be higher. The optimal density also depends on whether the management is intended to restore or to simply maintain habitat, with restoration management requiring higher stocking densities than maintenance management. The best way to establish the optimum grazing regime is by trial and careful observation of ground conditions, condition of the grazing livestock, and the effect of grazing on habitat structure and species composition.

Areas with breeding Aquatic Warblers should be either exempt from grazing from early May till the end of the breeding period, or be grazed only at especially low densities and preferably with mother cows or oxen to

▼ **Fig. 4.5.5**
Konik grazing in wet reed and sedge vegetation in the RSPB Minsmere Nature Reserve (photo: D. Tipling).

limit disturbance of breeding birds or the trampling of nests. Depending on the effectiveness of grazing and the productivity of the site, it might be necessary to mow remaining vegetation after the grazing season in late summer, autumn, or winter.

If the need for vegetation management for Aquatic Warblers or other species requires this, higher short-term stocking densities may be appropriate in early spring just before the breeding season and in late summer and autumn after breeding. Autumn grazing thereby opens out the sward by removing summer growth and helps finer grasses and herbs to gain a foothold. It also allows the majority of wetland plants to set seed. Spring grazing hits hardest those species which start growing early. These are often the most competitive species, such as Common Reed (*Phragmites australis*) and Reed Canary Grass (*Phalaris arundinacea*). Birch scrub and *Molinia* grass can also be reduced by spring grazing. Spring grazing should only be implemented if damage to any other protected ground-breeding birds can be excluded.

To co-finance grazing in Aquatic Warbler habitats, European Commission, national and regional incentive payments may be used (Chapter 5). The current package of the Polish agri-environmental and climate scheme applicable to Aquatic Warbler habitats is adjusted to the recommended grazing densities (see also **Box 5.4**). In the previous 2007-2013 scheme, which will be in use until 2019 in sites that applied it until/in 2014, grazing densities in some cases were not sufficient to obtain the desired management effect, e.g. through the ban of grazing during late autumn, winter, and early spring. There is an exception for Polish Konik horses in the old scheme, which can be grazed throughout the year, making them in some cases the current animal breed of choice in Aquatic Warbler conservation (Lachmann & Zadrąg 2011). The combination of low-intensity grazing with late summer or autumn mowing is also possible. Future Natura 2000 management plans should address these issues, however, and prescribe site-specific management rules, while also distinguishing between restoration and maintenance management.

4.6 Controlled burning

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Fire set by a lightning strike must have once burned fens in the European landscape as it is reported for mires in Finland (Pitkänen et al. 1999), and so could be considered as a natural disturbance and a management tool at least for undrained fens (Middleton et al. 2006). In most breeding range countries, especially in Belarus, Ukraine, Poland, and Germany, fire was also set on purpose: local people used to burn old vegetation early each spring in order to increase hay harvests from wet fen mires. About 20-30 years ago burning became widely illegal, not least due to pressure from the nature conservation movement (see also Chapter 4.1). Nature conservationists, especially in protected areas, were keen to prevent fires due to their devastating effects, such as those in 1994 affecting more than 3,000 ha in the Biebrza Valley in Northeast-Poland. The subsequent massive mineralisation of peat not only destroyed habitat and caused health problems due to intense smoke for local inhabitants, but also led to substantial emissions of greenhouse gases. Severe peat fires destroyed huge peatland areas also in the Moscow region in 2010. In addition, uncontrolled burning destroyed the Aquatic Warbler breeding sites Hrechyshcha-Shlapan and Lubiąż Lake in 2016 (see also Chapter 3). Here, Aquatic Warbler numbers decreased from 110-135 (2014) to 2-4 males (2016; A. Poluda pers.comm.). Only recently, the burning of peatland vegetation has been reintroduced as a useful tool for habitat management in specific sites.

Burning of peatland vegetation is currently illegal in all breeding range countries (e.g. in Poland according to article 124 of the Nature Conservation Act, article 30 of the Forest Act, and article 3.1 of the Minimum Standards Regulation). In some countries, however, it has recently become possible to obtain special permission for the controlled burning of peatlands. In Poland, this is only a theoretical possibility as liability issues prevent the granting of such permissions, while in Germany such permissions can be obtained. In Belarus, the Animal Law was changed in 2005 to allow for prescribed burning to improve habitat conditions of rare species and for the conservation of unique ecosystems.

Effects on flora and fauna

The (few) studies on the effects of controlled burning (mainly done in heathland and grassland, in North-America also in wetlands) generally showed that burning imitates the effects of mowing (Goldammer et al. 1997), possibly with an additional small fertilising effect (Allen 1966), and an extension of the spectrum of flowering plants (Schreiber 1997, Middleton 2002). Winter burning does not seem to be successful in reducing the cover of shrubs (Middleton 2002).

Studies on the effects of mowing and burning on invertebrates showed no difference in the number of species and individuals between mown and burned areas one year after fire (Ditlhogo et al. 1992) and a low promotion of thermophilic insects (Handke 1988, 1997). The number of locust species showed no mid-term decrease after burning (Driessen et al. 2006).

For the Aquatic Warbler, it is assumed, based on practical experience from Belarus (A. Kozulin unpubl. data), that:

- partial winter burning of old vegetation prior to the breeding season leads to an increase in Aquatic Warbler density in the same year;
- complete burning of old vegetation leads to the same density and reduced breeding success, with a positive effect on density only after a few years;
- when also mosses and the uppermost peat layer are burned, this leads to a decrease in Aquatic Warbler density by one third in the subsequent year, followed by a recovery to the level before burning after three years;
- deep burning (more than 20 cm) of the

peat leads to the abandonment of the site by Aquatic Warblers for at least two years; restoration begins in the third year after deep burning.

Thanks to various behavioural characteristics, such as the ability to use burned tussocks or only fresh plant material for nests (Vergeichik & Kozulin 2006b; see Chapter 2.5), the species is generally quick to adapt to changing conditions after burning. However, in all but the first case, the negative effects on the population dominate. Any use of prescribed burning should therefore aim at only partial burning of old vegetation without burning of moss or peat layers. Compared to winter mowing, controlled burning has the advantage of not affecting soil density by ground pressure of the mowing machines. But in contrast to winter mowing (with biomass removal), it does not remove plant biomass from the site and has thus probably a (small) fertilising effect.

Recommendations for controlled burning as a management tool

Where burning is carried out at water levels below soil surface, it causes substantial damage to the ecosystem by destroying the upper peat layers and tussocks, and thus also invertebrates as well as small mammals. After such fires, it takes several years for the ecosystem to restore. However, if the burning is carried out at higher water levels and carefully controlled, it can be instrumental in maintaining plant productivity and limiting the overgrowth of shrubs. Hence, prescribed burning is the most effective when the surface of the fen is covered with ice or snow and the dry vegetation remains over the frozen peat layer. In this case, only the upper part of the vegetation layer is destroyed and the fire does not spread to surrounding areas.

It is generally recommended to use controlled burning as a management tool only in the period from November until end of March and if:

- the peat soil surface and the vegetative parts of the plants up to the tops of tussocks are covered with ice, snow, or water;
- the surrounding areas are also covered with snow or are at least moist;
- it is likely that water levels during the subsequent breeding period will not be extremely high (as under very wet conditions, the lack of litter would worsen nesting conditions).

Under such conditions (**Fig. 4.6.1**), it is most likely that only old vegetation is partially burned and that neither the peat nor the surrounding areas are affected. It is not necessary to aim for the complete burning of an area under management. Instead, a mosaic of burned and unburned patches can create a beneficial micro-mosaic in the habitat. Burning the areas with the wind leads to a faster progress of the fire, lower temperatures on the ground and less complete combustion of the vegetation. Therefore, in most cases, this should be the preferred method of burning.

Generally, for the conservation of Aquatic Warbler habitats, it is necessary to combine controlled burning with other measures aiming at water level management, as well as removal of shrubs and of high, dense vegetation.

In order to decide whether burning is a suitable management tool for a particular site that can replace mowing or grazing, it is necessary to consider the trophic level of the site: the more nutrient-rich it is, the less effective burning is as a habitat maintenance tool, and even less so as a habitat restoration tool, since a large part of the nutrients fixed in the vegetation will remain on site. In such a situation, mowing with the removal of biomass would be more suitable, as this contributes to the removal of nutrients from the site. For this reason, burning is not suitable for regular use in eutrophic Aquatic Warbler sites, which require annual management (see Chapter 4.1). It is probably suitable for most sites that require only sporadic management every 3-5 years or more. In mesotrophic fens that are substantially influenced by surface waters (e.g. Zvaniec, Sporava), the eutrophication effect of winter burning seems to be overridden by the degree of spring flooding with nutrient-rich surface waters.

Any controlled burning action should be accompanied by suitable public relation measures. Otherwise, there is the danger of increased illegal and uncontrolled fires set by the local population during unfavourable conditions.

The obvious advantage of controlled burning as a management tool is the low costs of the measure, which are normally restricted to a suitable number of fire guards and possibly prior creation of firebreaks around the area to be burned. This is especially important in large sites, for which the costs of mechanical mowing would be prohibitive. Disadvantages are the administrative efforts required to obtain permission and the essential intensive public relations work. It is also necessary to wait for suitable conditions, which in most sites do not occur every year. In addition to that, not every site is suitable for controlled burning, as it may be difficult to contain a fire within the site due to a lack of natural firebreaks.

Practical experience in Belarus

The key study site showing the effects of controlled burning in Belarus is Zvaniec. The first controlled winter fires were set to prevent the frequent (1995, 1997, 2001, and 2004) catastrophic spring fires triggered by delayed spring flooding. The severe losses for the peatland ecosystem could be assessed in spring 2001, prior to which the mire had burned at the time of a very low

▼ **Fig. 4.6.1**
Suitable conditions for controlled burning in a Belarusian fen (photo: A. Kozulin).

ground water level. At the Aquatic Warbler monitoring plot, which is located in the southern part of the mire, the water table was close to soil surface during the fire. Here, only Reed and much of the sedge biomass were burned. In the drier northern and eastern parts of the mire the uppermost peat layer burned, and by May vegetation was still virtually absent. As a result of this fire, an area of c. 3,000 ha (the northern part of the mire) was not suited for Aquatic Warbler breeding in May/June 2001. Single birds appeared there only in July (Kozulin & Vergeichik 2006). The overall number of singing males in 2001 was almost two times lower than previously.

Controlled burning of vegetation in Zvaniec was conducted for the first time in December 2007. The water level in autumn was higher than the tussocks and the conditions for burning became optimal just after the freezing of water. About 6,000 ha of the mire vegetation was burned. Old Reed stems were totally destroyed and sedges were burned partially. A considerable part of dry vegetation was preserved on the tussocks, which ensured the necessary conditions for nest building of ground-nesting birds as well as the survival of wintering stages of invertebrates wintering in plant stems. The next prescribed burning in Zvaniec was planned for the winter 2009/2010, however, as the water level was too high and the layer of snow was too thick, leaving not enough biomass above the water or snow surface to be burned, it was not administered until February 2015 (**Fig. 4.6.2**). During the second controlled fire, some 9,000 ha of fen were burned, including old vegetation as well as willow shrubs and young birch trees. Vegetation regenerated the same spring (**Fig. 4.6.3**), with sedges reaching 30 cm (50% of the typical height) by mid-May (**Fig. 4.6.4**) and growing to their full height by the end of May, and sparse reeds growing higher than sedges by the second half of June. The low plant productivity and severe lack of arthropod biomass observed in 2015 in the whole area of Zvaniec is attributed to the catastrophic drought (water table 30-150 cm below soil surface) caused by the complete lack of

▲ **Fig. 4.6.2**
Controlled fire at the monitoring plot Navasiolki, Zvaniec, Belarus, 17 February 2015 (photo: M. Maximenkov).

◄ **Fig. 4.6.3**
The Aquatic Warbler monitoring plot Navasiolki, Zvaniec, Belarus, after burning in February, 7 May 2015 (photo: A. Kozulin).

◄ **Fig. 4.6.4**
The Aquatic Warbler monitoring plot Navasiolki, Zvaniec, Belarus, after burning in February and with a water table of c. 30 cm below soil surface, 14 May 2015 (photo: A. Kozulin).

▼ **Fig. 4.6.5**
The Aquatic Warbler monitoring plot Navasiolki, Zvaniec, Belarus, one year after burning, 5 July 2016 (photo: A. Kozulin).

4.6

▲ **Fig. 4.6.6**
Vegetation structure on the unburned part of the Aquatic Warbler monitoring plot Navasiolki, Zvaniec, Belarus, under dry conditions, 20 May 2015 (photo: A. Kozulin).

► **Fig. 4.6.7**
Willow (*Salix* spp.) regeneration after fire, Zvaniec, Belarus, May 2015 (photo: A. Kozulin).

flooding (A. Kozulin pers. comm.).

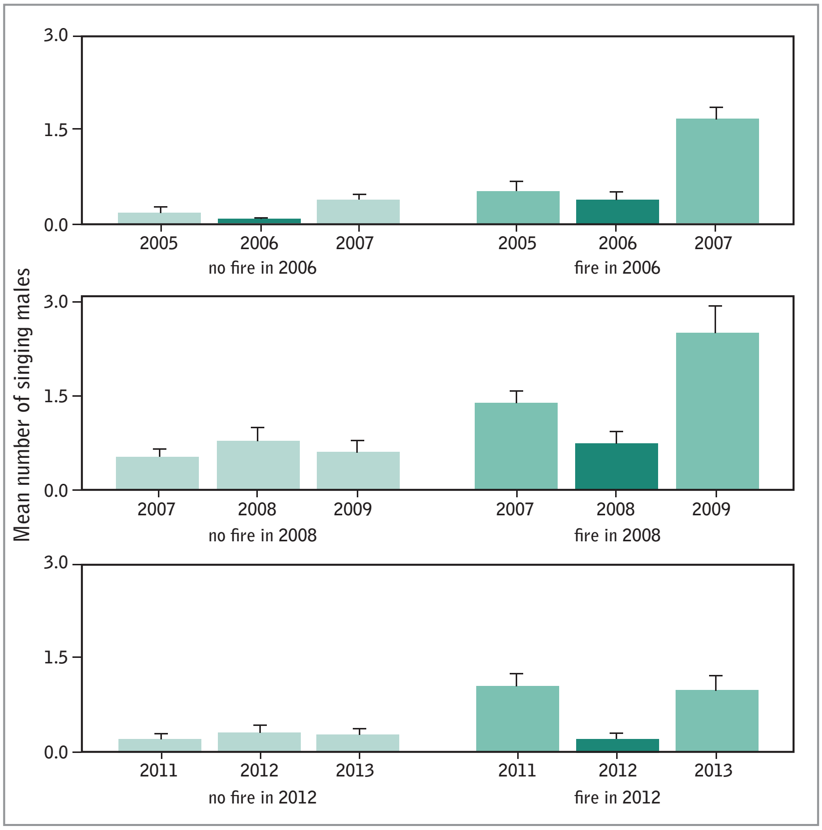
Currently, controlled burning is seen as a tool to reach the following objectives:

- to prevent uncontrolled spring fires;
- to enable Aquatic Warbler breeding on areas overgrown with Reed. After controlled fire at Zvaniec, new stems have a similar height as the sedges during the first clutch and Aquatic Warblers can use such areas (but at the end of June, when reed is higher than 1.5 m, they leave the site; **Fig. 4.6.5**);
- to reduce the amount of litter (**Fig. 4.6.6**) and thus to increase light and temperature at the soil surface in spring and correspondingly annual plant and arthropod productivity, considered as favourable for breeding birds, including the Aquatic Warbler;
- to control or at least reduce willow overgrowth (only feasible if winter fire is repeated after two years, **Fig. 4.6.7**).

Practical experience in other breeding range countries

In Poland, accidental burning of calcareous fens in the Bagno Serebryskie Reserve (Chełm Marshes, near Lublin) in Southeast-Poland in late 2006, in 2008, and in early May of 2012 coincided with an increase of the density of Aquatic Warbler singing males (**Fig. 4.6.8**; Grzywaczwski et al. 2014). In addition, a breeding productivity study carried out in the same reserve between 2012 and 2015 also showed a high density of singing males and, importantly, a boost of nest densities one year after fire (**Fig. 4.6.9**; Kubacka et al. in prep.). The burned habitat was completely unsuitable for Aquatic Warblers in 2012 (as the fire was on 2 May), when only bare ground was available, and became overgrown with high reeds by the end of the season. During second broods, first singing males were recorded to use the reeds. The habitat regenerated fully by the next year and was nearly indistinguishable from the unburned section of the mire two years after fire. A similar effect was noted in the southern basin of the Biebrza Valley, where at a few sites which were burned down at least one year before the 1997 census, an increase in Aquatic Warbler numbers was observed compared to the previous 1995 survey (Kloskowski & Krogulec 1999). However, fire as a conservation tool cannot currently be used in Poland because of the existing legal situation and the prevailing interest not to sacrifice the achievements of the decade-long fight against illegal fires on fields and meadows, as well as fears over liability issues.

In Germany, there were plans to carry out controlled burning within the EU-LIFE-project 'Conserving *Acrocephalus paludicola* in Poland and Germany'. Permission was issued in 2006 by nature conservation authorities for burning vegetation on 40 ha in the polder Johannishof in the Lower Peene Valley (Tanneberger et al. 2007). Unfortunately, in successive winters 2006/2007 through to 2009/2010 the weather and water level conditions were not suitable, especially since the dike of the abandoned polder was collapsing and the site was flooded with increasing frequency. This site, therefore, probably has to be considered unsuitable for burning management, because favourable conditions for burning do not occur sufficiently often, so that other management methods need to be considered.

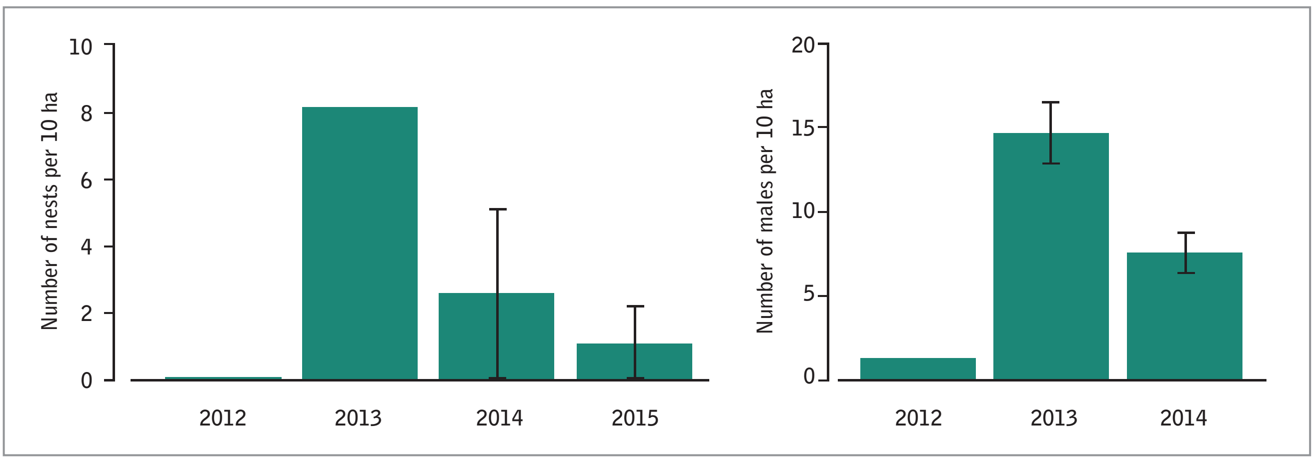


▲ **Fig. 4.6.8**

Mean number (+standard error) of Aquatic Warbler singing males in plots unaffected and affected by fire (left- and right-hand side of each graph, respectively) in 2006, 2008, and 2012 (top, middle and bottom graph, respectively) in the Bagno Serebryskie Reserve, Southeast-Poland. Reproduced with permission from Grzywaczewski et al. (2014).

▼ **Fig. 4.6.9**

Aquatic Warbler nest densities (first broods only; left graph) and male densities (averaged across the two breeding peaks; right graph) in the Bagno Serebryskie Reserve, Southeast-Poland, in the area that was destroyed by fire on May 2 2012 (Kubacka et al. in prep.). **Bars are means ± standard errors.**



4.7 Habitat restoration

FRANZISKA TANNEBERGER

In all the countries with current Aquatic Warbler breeding records, the area occupied by the species is smaller than it was in the past. In addition, several European countries have completely lost their breeding Aquatic Warblers (e.g. Austria and the Netherlands, and recently also Hungary). This means that there is now a very large area of abandoned former breeding sites that could potentially be restored (see also Chapter 3). Typical key activities in habitat restoration for Aquatic Warblers are the initial improvement of the hydrological regime (Chapter 4.2) and subsequent vegetation management (Chapters 4.3-4.6). In order to secure the hydrological conditions and vegetation management necessary for the restoration and maintenance of Aquatic Warbler habitats, conservation activities should seek synergies with peatland restoration for climate protection and paludiculture (i.e. agriculture or forestry on wet peatlands; see Chapter 5).

Restoration strategies

The restoration of Aquatic Warbler breeding habitats can follow various strategies:

- to enlarge the suitable area within or adjacent to current breeding sites;
- to restore sites that have been abandoned by Aquatic Warblers, ensuring they are close enough to existing sites to enable recolonisation; and
- to identify and manage sites that have significant potential as Aquatic Warbler habitats (but where no historical records exist).

The enlargement of current breeding sites is clearly the most promising approach as it is the most likely that the birds will accept the additional habitat and spread there (at least if the pressure within the population is large enough). Several conservation activities are aimed at enlarging habitats in or close to existing breeding sites, e.g. the Polish-German LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (2005-2011) at the project sites Wolin National Park, Karsiborska Kępa, and Biebrza National Park.

The identification and restoration of additional sites that are currently not occupied by the species is, however, also crucial for the conservation of the species. It will not be possible to achieve the long-term target set out by the International Aquatic Warbler Species Action Plan (Flade & Lachmann 2008) to increase the species' area of occupancy (AOO) by 50% by 2025 only through the restoration of degraded areas at existing sites. Importantly, achieving this target is necessary in order to justify removing the species from the list of globally threatened species.

Conservation activities, therefore, also need to focus on efforts at sites that either already provide a similar habitat, or used to have a suitable habitat that later degraded, e.g. due to drainage, land use abandonment, or land use intensification. When choosing restoration sites, priority should be given to those that can become stepping stone habitats able to connect subpopulations. At the same time, they should not be too far from potential source populations to provide a reasonable chance of colonisation.

For Poland, it is recommended that effort is given to increasing the number of stepping stone patches between the viable large eastern subpopulations and the smaller central and western ones in order to increase dispersal among subpopulations, and thus to mitigate the negative trends and increased risk of local and regional extinction in the western and central parts of Poland (Żmihorski et al. 2016). Such priority sites for habitat restoration are described in Krogulec & Wołczuk (2014), proposing concrete habitat restoration measures and outlining potential costs. In 2017-2019, OTOP BirdLife Poland is implementing the project 'Strengthening the south-eastern metapopulation of *Acroce-*

phalus paludicola in Poland' (funded by the EU's Operational Programme Infrastructure and Environment 2014-2020). Within this project, appropriate habitat conditions for the Aquatic Warbler are restored in historical or potential areas of occurrence of this species.

In Lithuania and Belarus, the EU LIFE project 'LIFE MagniDucatusAcrola' (2016-2023) aims to create stepping stone habitats towards ensuring a long-term favourable conservation status of the Aquatic Warbler. The project will perform restoration measures at degraded habitats in Lithuania (e.g. Apvardai in eastern Lithuania) as well as the areas in Belarus which are close to the Lithuanian (EU) border and are the best candidates to function as 'stepping stones' (Dakudauskaje, Servech). At Dakudauskaje (**Fig. 4.7.1**), sedge seeds and vegetative parts from typical Belarusian Aquatic Warbler habitats will be spread on c. 177 ha prior to raising water levels.

▲ **Fig. 4.7.1**
Large parts of Dakudauskaje in Northwest-Belarus have been used for peat extraction. Within the EU LIFE project MagniDucatusAcrola (2016-2023), it is planned to raise the water level on more than 1,000 ha and to restore fen mire habitat (photo: N. Tanovitskaya)**.**

Identification of potential restoration sites

In order to direct available resources for site restoration in the most effective way, it is necessary to identify the most promising restoration sites. Starting points are inventories of previously occupied Aquatic Warbler sites and sites with Aquatic Warbler habitats, and the analysis of terrestrial data (e.g. soil maps, biotope maps, and vegetation maps) as well as remote sensing data (e.g. satellite images). Based on this analysis, and reinforced by expert knowledge and ground checks, priority areas for habitat restoration in a specific region can be developed (e.g. as in the Brandenburg Species Action Plan, see **Box 4.7.1**).

Box 4.7.1

Identification of sites for habitat restoration in Brandenburg (Germany)

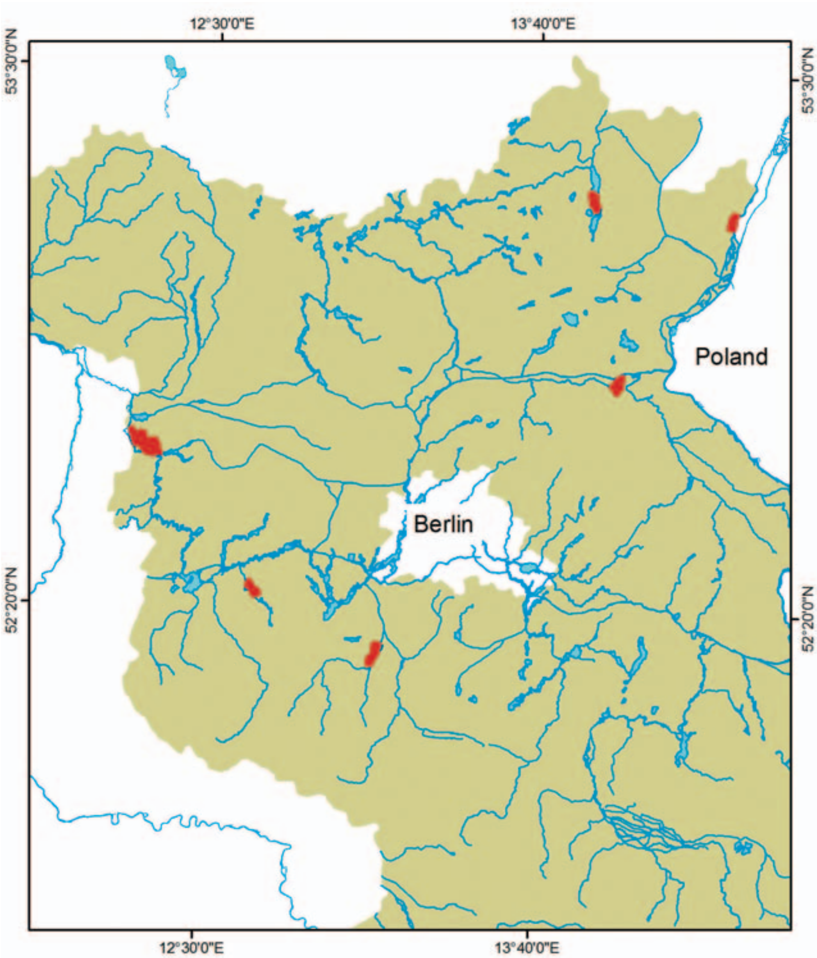
FRANZISKA TANNEBERGER, JOCHEN BELLEBAUM & ANNETT FRICK

For the Species Action Plan for the Aquatic Warbler in Brandenburg (Germany) (Tanneberger et al. 2010b), species distribution models based on satellite and environmental data were developed to identify potential areas for Aquatic Warbler habitat restoration (Frick et al. 2014). Brandenburg (Northeast-Germany, 29,478 km^2) used to be a stronghold for the species, with at least 15 active breeding sites in the early 20th century. A total of 3,785 km^2 is covered with soil types consistent with those found at sites with historical Aquatic Warbler records. This figure, however, includes an unknown number of sites that were always unsuitable due to size, isolation, or vegetation (Tanneberger et al. 2010b). Since 1979, only one active breeding site (Lower Oder Valley National Park) has remained in Brandenburg, and the last record of a singing male at this site was in 2013.

Remote sensing data is increasingly being used to map the extent of potentially suitable habitat (e.g. Osborne et al. 2001, Jeganathan et al. 2004, Buermann et al. 2008). The study on Aquatic Warbler habitat restoration sites in Northeast-Germany used IRS (Indian Remote Sensing satellite) images captured mainly in April-June 2005 and MODIS (Moderate Resolution Imaging Spectroradiometer) data. To arrive at reliable guidance for habitat restoration, all Aquatic Warbler records in the study area since 1990 were used and combined with satellite data as well as several environmental factors (habitat type, soil type, elevation, distribution of grassland). ►

4.7

Box 4.7.1 contd Model integration with the metamodel (following a multiple modelling approach suggested for example, by Araújo & New 2007, Dormann et al. 2008, and Grenouillet et al. 2011) applied to the whole mask of 3,785 km^2 yielded 621 km^2 of potentially suitable habitat. After excluding all sites smaller than 200 ha, the final result comprises 293 km^2. Based on a set of additional criteria, such as synergies with ongoing projects and the likelihood of land use conflicts, six priority areas for habitat restoration in Brandenburg covering 4,748 ha in total were identified (**Fig. 4.7.2**).



▲ **Fig. 4.7.2**
Priority areas for habitat restoration in Brandenburg, Germany (from Tanneberger et al. 2010b).

Hydrological restoration

Once a peatland is drained, peat consolidation, compaction, and oxidation leads to changes in the hydrological and hydraulic conditions and, as a consequence, mire development may be affected permanently (Joosten 2016b). These impacts have been well-known for centuries, and form the basis of approaches to mire restoration (Tanneberger et al. 2017a). The world's very first scientific book on peatlands (Schoockius 1658) already included a chapter on peatland restoration. About one hundred years later, J.C. Findorff (1720-1792) described the renewed growth of peat in some former extraction areas, and warned not to expect a fast regeneration process (Findorff 1764). While much knowledge about restoration has been collected from trial sites, the restoration of larger areas in most countries only commenced at the end of the 20th century, and intensified in the early 21st century as part of climate change mitigation (Tanneberger & Wichtmann 2011).

Commonly applied restoration measures include rewetting by blocking outflow in drainage ditches, installing bunds, removing dikes, ending pumping in polders, topsoil removal (**Box 4.7.2**), and also the removal of trees and shrubs to reduce evapotranspiration and competition with peat-forming species and to restore an open habitat (Tanneberger et al. 2017a).

Repairing the hydrological regime of a wetland is more complex than just raising water levels. In groundwater-fed fens, in particular, increasing water levels may lead to acidification when the discharge of base-rich groundwater cannot be reinstated. Therefore, successful management of ground-water-fed fens should be approached at a broader scale that includes the landscape-scale management of ground-water systems. Not only quantitative aspects are important but also qualitative aspects (Grootjans et al. 2012). Leaching of nitrate to the groundwater, for instance, can cause large-scale mobilisation of sulphate from geological pyrite or gypsum deposits and the immobilisation of ferrous iron (Smolders et al. 2010). In addition, the mobilisation of phosphorous, organic carbon, and ammonium is a common feature after fen rewetting (Zak & Gelbrecht 2007). A landscape-scale approach often implies changing land use in the entire surrounding catchment area. This requires stakeholder participation. Without that support, fen restoration is almost unachievable due to conflicting land use claims (Klimkowska et al. 2010).

Major rewetting projects in the Aquatic Warbler breeding range

In Belarus, early rewetting initiatives were rejected by the authorities until the end of the 20th century, but after the 2002 drought, when the majority of the large depleted peatlands burned, the attitude of the authorities changed completely. An expert group showed that peat fires occurred mainly on drained and abandoned peatlands, and the area of drained and degrading, ineffectively used peatlands was estimated at 500,000 ha. As part of a United Nations Development Programme (UNDP)/Global Environment Facility (GEF) project for the restoration of peatlands (2006-2010), two Technical Codes of Established Practices consistent with Belarusian law and practical guidance on peatland rewetting (Kozulin et al. 2010) were developed (Bambalov et al. 2017). Thanks to a second large rewetting project funded through the German International Climate Initiative (2008-2012), peatlands were recognised as an acceptable project category under the Verified Carbon Standard (VCS) in 2011 and a VCS methodology for assessing greenhouse gas emission reductions from rewetted peatlands was developed. The project thus facilitated financing peatland rewetting via carbon credits (Tanneberger & Wichtmann 2011). These two projects resulted in the rewetting of 28,207 ha. A number of smaller rewetting projects have been prepared and implemented by APB BirdLife Belarus with funding through the GEF Small Grants Programme, including activities on Jelnia and Dakudauskaje. By 2013, a total of 51,486 ha had been restored (Nikiforov et al. 2013), including several potential Aquatic Warbler breeding sites such as Hrycyna-Staronbinskaje (**Fig. 4.7.3** and **4.7.4**).

Germany was among the first countries to implement mire restoration over large areas, following a devastating history of mire exploitation. Some 28,000 ha have been rewetted in the northeastern federal state of Mecklenburg-Vorpommern since 1990 (Tanneberger et al. 2017), including areas such as the Peene Valley, a former Aquatic Warbler breeding site. At the mouth of the river Peene, where Aquatic Warbler bred until 1978, hydrological restoration by closing ditches and stopping pumping of polders was supported by the Polish-German LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (2005-2011) and implemented success-

▲ **Fig. 4.7.3**
Before rewetting, the fen Hrycyna-Starobinskaje, Belarus was covered by ruderal vegetation indicating dry conditions as well as by fields of bare peat and areas with shrubs and trees, August 2009 (photo: A. Thiele).

▲ **Fig. 4.7.4**
After rewetting, the high water level at Hrycyna-Starobinskaje, will lead to trees and shrubs dying off, and to an extension of areas with vegetation indicating wet conditions, August 2010 (photo: S. Koltovich).

fully. The site has now a long-term median water level of +10 to -10 cm relative to soil surface and largely suitable vegetation (**Fig. 4.7.5**), but to date Aquatic Warblers could not be attracted.

In Poland, hydrological restoration by blocking outflows in drainage ditches is a commonly applied measure in peatlands, though it lacks systematic financial support, as in the case of mowing, and can only be implemented as part of dedicated projects, e.g. financed by the EU LIFE programme or similar funds (Kotowski et al. 2017). Only less than 500 ha of heavily degraded peatlands have been rewetted deliberately. Including also mires that have been in a relatively good shape and where ditches have been blocked to remove shallow drainage, then that figure rises to perhaps 1,000-2,000 ha. The area of rewetted peatland in Ukraine, Lithuania and Hungary is relatively small.

Vegetation development after rewetting

Depending on the level of peat soil degradation before rewetting and the water table after rewetting, the restoration process of degraded fens to suitable Aquatic Warbler habitat can take a long time. On extracted fen sites in Belarus, with oligotrophic site conditions and water levels after rewetting close to the surface (-10 cm to +10 cm), a transient vegetation cover of a sparse *Phragmites australis* vegetation with *Eriophorum angustifolium*, *Carex vesicaria*, *Lythrum salicaria*, and *Trichophorum alpinum* developed within two years. Under meso- and eutrophic conditions and with mean water levels up to the surface *Salix* spp. and species such as *Calamagrostis canescens*, *Lysimachia thyrsiflora*, and *L. vulgaris* establish together with *Carex* species like *C. vesicaria*, and *C. elata*. With water levels above 20 cm, a mono-domi-

▼ **Fig. 4.7.5**
Restored fen mire at the mouth of the Peene River (Northeast-Germany), an Aquatic Warbler breeding site until 1978, July 2017 (photo: S. Busse & T. Dahms).

nant *Phragmites australis* stand will develop. When water levels remain above 30 cm, water plants like *Myriophyllum alternifolium* and *Calla palustris* will establish (Kozulin et al. 2010, Thiele et al. 2011).

On drained and degraded but not extracted fen sites, the transition from grassland species to wetland species often starts with open water and single *Typha* spp. islands, accompanied by *Phragmites* stands with *Glyceria fluitans* and *G. maxima*, and eventually developing into *Carex* communities (Timmermann et al. 2006, Steffenhagen et al. 2010, Thiele et al. 2011). Colonisation by *Carex* species may take as long as twelve years (Holsten et al. 2001, Steffenhagen et al. 2008). Strongly eu- or polytrophic stands with non-peat-forming plants like *Typha* spp. develop on inundated sites, while eu- or mesotrophic stands with e.g. *Phragmites australis*, *Phalaris arundinacea*, *Angelica sylvestris*, and *Epilobium palustre* develop on sites rewetted up to or slightly below the soil surface (Schulz 2005, Thiele et al. 2011).

Based on the rewetting experiences of Belarus and Germany, it is assumed that a period of about 30 years from the moment of rewetting a degraded fen mire to the point when it could become suitable for Aquatic Warblers is realistic. However, on less degraded sites, and especially in cases where source subpopulations are close-by, restored sites can be re-occupied much earlier, as it happened recently in the Ciesacin Mire near the Poleski National Park (South-east-Poland) and the German Lower Oder Valley National Park (northern part, see Chapter 4.2).

Box 4.7.2

Fen restoration by topsoil removal and the reintroduction of vegetation

INGO KOSKA, FRIEDRICH HACKER & BENJAMIN HEROLD

Topsoil removal in peatlands implies the cutting and removal of the upper peat layers and vegetation. The bare peat is less degraded, more nutrient-poor, and usually closer to the groundwater. In contrast to closing and filling drainage ditches, topsoil removal is aimed primarily at rewetting the peat soil, but also at achieving nutrient-poor conditions.

When applying topsoil removal, sound planning is needed. An analysis of peat types, plant macrofossils, C/N-ratio, and pH value should be carried out to determine suitable sites (cf. Succow & Joosten 2001). Potential sources of eutrophication in the surroundings need to be identified and avoided. The depth of topsoil removal is determined by the depth of peat degradation and the target levels of nutrient removal and groundwater table. In particular in sloping fens, the creation of low barriers, or a honeycombed arrangement of the topsoil removal plots, can reduce the risk of erosion, improve water retention, mimic the development of hollows, and limit emerging shrub and tree seedlings at an early stage. Best practice at current topsoil removal sites is to use the removed soil as filling material for adjacent ditches, keeping costs low. However realised areas are of moderate size (<2 ha, mostly ~ 0.5 ha).

On fresh bare peat, a near-natural peatland vegetation can establish spontaneously by dispersal from local sources. However, in most peatlands the surrounding areas no longer feature pristine vegetation. In particular, nutrient-poor, base-rich habitats persist only in isolated and remote locations. The long distance dispersal of many typical fen plants is therefore limited. Active vegetation reintroduction can effectively support the regeneration of typical species combinations and their (self-) regulating functions (Patzelt et al. 2001, Matus et al. 2003, Klimkowska 2008).

Topsoil removal with the reintroduction of plants was first applied in heaths, dry grasslands, and wet meadows in the Netherlands (van Diggelen et al 1997, Verhagen 2007, Klimkowska et al 2007, 2010, Klimkowska 2008, Hedberg et al. 2013) and in the foothills of the Alps (Ramseier 2000, Kratz & Pfadenhauer 2001, Schächtele & Kiehl 2005). These authors also discussed the prospects of restoring nutrient-poor fens and bogs through the removal of topsoil. The first projects for the restoration of primarily nutrient-poor, calcareous fens were conducted in Brandenburg, Germany. Schumann & Mauersberger (2009) report on the good effects of topsoil removal without the active reintroduction of vegetation. Under the project 'Kunsterwiese' (Koska & Hacker 2013), 'Beesenberg' (Koska et al. 2014), and the EU LIFE project 'Calcareous fens in Brandenburg' (2012-2015; Rößling et al. 2012, Koska & Hacker 2015), topsoil removal and the reintroduction of vegetation were applied at several sites with a total area of c. 11 ha. These activities are currently being continued within the EU LIFE project 'Schreiadler Schorfheide-Chorin' (2012-2019) in the Sernitz Valley on 8-10 ha (Herold 2013). ►

4.7

Box 4.7.2 contd In the Brandenburg projects, the topsoil was removed by excavator or caterpillars (**Fig. 4.7.6**). The reintroduction of plants took place in the following spring or autumn. Moss-rich sods were cut in near-natural fens, shredded and distributed on the topsoil removal sites with a coarse sieve (**Fig. 4.7.7**). The shredded material contained plant parts able to sprout, seeds, other propagules as well as animals and microorganisms. In addition, seeds and moss shoots were separately collected and applied for particularly rare target species in order to ensure their successful colonisation and to protect the donor populations by controlled removal. The time required to establish a near-natural moss and herb layer (**Fig. 4.7.8**) depends on the amount of distributed shredding material. Amounts of 10-100 g/m² facilitated an almost closed vegetation cover after 3-5 years, 10 g/m² take about 5 years. In order to restore 1 ha, by an amount of 100 g/m² only 60 m² of a near-natural donor site have to be harvested, with 10 g/m² only 6 m².

Topsoil removal, especially when combined with the introduction of target species, seems to be effective in quickly restoring low-productive fen mire vegetation. Thus it could be also useful in the restoration of Aquatic Warbler habitats. For this, however, significantly larger areas would need to be restored than currently practiced. From a technical point of view, this is feasible, but would require a solution to cover the high costs and to utilise the large amounts of removed peat in a meaningful way, e.g. as agri- or horticultural substrate, as well as public acceptance.

▼ **Fig. 4.7.6**
Snow groomers with a dozer blade remove the degraded topsoil, exposing wet and nutrient-poor peat, Sernitz Valley, Germany, EU LIFE project 'Schreiadler Schorfheide-Chorin', October 2015 (photo: B. Herold).

▲ **Fig. 4.7.7**

Distribution of shredded plant material from donor sites on bare peat in the Sernitz Valley, Northeast-Germany, in the EU LIFE project 'Schreiadler Schorfheide-Chorin'. The topsoil was removed six months earlier. A system of chambers improves water retention, August 2016 (photo: F. Hacker)**.**

▲ **Fig. 4.7.8**

Almost-closed vegetation cover one year after reintroduction. *Phragmites communis* **remains in areas where no top soil has been removed, Sernitz Valley, Germany, EU LIFE project 'Schreiadler Schorfheide-Chorin', summer 2017** (photo: B. Herold)**.**

5 Conservation funding

5 Conservation funding

LARS LACHMANN, JUSTYNA KUBACKA & FRANZISKA TANNEBERGER

The Aquatic Warbler today is essentially a conservation-dependent bird species. These days, after decades and centuries of human interference with local water systems and agricultural activity, hardly any breeding site of this species remains that would maintain good breeding conditions without any conservation intervention (see Chapter 4.1). At the same time, for hundreds of years, human land use has maintained Aquatic Warbler habitats in good condition for the species, often keeping fen mires open by low-intensity mowing by hand for hay and bedding for livestock (**Fig. 5.1**). Only when this type of extensive land use ceased to be implemented – at various times throughout the 20th century – the changes to the natural conditions that had been brought about in the centuries before made themselves apparent by rapid changes to the vegetation of the mires. Today, large parts of once open wetlands with fen vegetation would develop into wet forest if left alone – a common fate for mires put under formal protection without the necessary understanding or means to maintain the open fen habitat. At the other end of the scale, the alternative scenario is intensification of land use brought about by the attempt to increase yields through drainage of the land, application of fertilisers, and increased mowing frequency, to become more competitive on the market. Unfortunately, this quickly leads to a vegetation structure and mowing dates that are unsuitable for Aquatic Warblers. This is the typical fate of areas that have not been put under any form of nature protection (see Chapter 3).

Maintaining habitat quality by continuing or imitating traditional land use practices (see Chapter 4.1) is costly. Restoring habitat that has already degraded to a state unsuitable for Aquatic Warblers is even more expensive. To prevent succession in a disturbed peatland, mowing or grazing needs to take place on a regular basis; and to restore a fen mire, rewetting or bush removal must be performed (Chapters 4.3 and 4.7). Especially more elaborate water management measures (Chapter 4.2) can be very expensive.

The budgets of national parks or nature reserves protecting today's most important Aquatic Warbler sites are normally not able to provide the necessary resources to this end. Additionally, with the aim being an increase of the area occupied by Aquatic Warblers – a precondition of getting the species off the list of globally threatened bird species – it is not possible to restrict conservation measures to existing protected areas. Aquatic Warbler protection also needs to take place in areas that are not under the auspices of a dedicated conservation administration.

Clearly, habitat management requirements make up the bulk of the funding needs for the conservation of Aquatic Warblers. But also research into the best way to protect the species, the monitoring of the efficiency of measures that are being taken, the dissemination of results, the planning of actions, the communication of relevant knowledge amongst species ex-

▼ **Fig. 5.1**
The end of traditional scything of fen mire vegetation spelled the onset of rapid successional overgrowth of Aquatic Warbler breeding habitats. Biebrza National Park, Poland, February 2008 (photo: L. Lachmann).

perts, conservationists, site managers, and public administrations, and not least the livelihoods of local people in and around Aquatic Warbler sites require appropriate funding.

This chapter will take a closer look at the funding needs for Aquatic Warbler conservation and explore the funding streams that have been used in the past and those that are relevant today and could be used in the future. As there is no such thing as a universal pot of money specifically targeted to protect this species, funds have to be sought from a very wide range of sources: starting from volunteer efforts, small grants from conservation organisations and small private foundations, moving on to large conservation projects funded by big international funds, to recurring subsidies for specific types of land use under a wider agriculture policy up to novel economic approaches like ecotourism, the use of biomass for energy production, or the financing of habitat restoration through carbon credits. But all these sources of money have strong and weak points, which are discussed where appropriate.

The costs of conserving the Aquatic Warbler

In 2012, BirdLife International and the Cambridge Conservation Initiative embarked on an exercise to estimate how much it would cost to save all the bird species currently classified as globally threatened on the IUCN Red List. The aim was to move each of these species into the next lower threat category within ten years and to ensure they can be maintained in this category in the long term. The result was that this would need 8.8 to 12.3 billion US Dollar during the first ten years, followed by regular needs for maintaining these conservation results (McCarthy et. al. 2012).

With the Aquatic Warbler being one of these species ('vulnerable' on the global IUCN Red List, see Chapters 2.1 and 2.2), this exercise has also been done for this species (L. Lachmann unpubl. data). Costs were estimated to move it from 'vulnerable' to 'near threatened' and keep it there. The reason for its classification as 'vulnerable' is its extremely small area of occupancy (AOO, see Chapter 2.2), which is the area actually occupied by breeding Aquatic Warblers at a certain geographical grid resolution. At the time, the AOO was estimated to be only about 360 km². In order to be moved to 'near threatened', the AOO would have to increase to at least 1,500 km². This aim is in fact identical to the medium to long-term target in the current International Aquatic Warbler Species Action Plan (Flade & Lachmann 2008), where the achievement of this aim is envisaged for 2020.

All in all, conservation funding needed to achieve this aim within ten years was estimated to be between 214 and 447 million US Dollar. Costs to maintain the results of this conservation effort were estimated to be around 31 million US Dollar per year thereafter. Recurring management costs associated with the existing and restored Aquatic Warbler habitats make up a lion's share of both of these estimates: about 90% for the first ten years and almost 97% in the following years. The difference is explained by the fact that the initial effort to increase the species' AOO requires the one-off restoration of large areas of habitat (c. 7% of the estimate for the first ten years), which is not included in the estimate for the following years. At the same time, the recurring management requirements are not going to decrease after the first ten years because, as outlined in Chapter 4.1, virtually all Aquatic Warbler habitats are nowadays dependent on some level of recurring management (**Fig. 5.2**).

Besides habitat restoration and management, the remaining 3% of conservation cost requirements include expenses for research and monitoring, political advocacy work, the designation of new protected areas, education, and awareness work as well as networking and capacity building.

These large figures may appear daunting at first. Especially the ongoing and possibly never-ending need for recurring management might dishearten conservationists or funders alike. But one should keep in mind that these costs are not net costs, but

▲ **Fig. 5.2** **The recurring management of thousands of hectares to maintain wide open fen mires as breeding sites for Aquatic Warblers is the biggest cost of saving the species. Ławki Mire, Biebrza National Park, Poland, May 2007** (photo: L. Lachmann).

the actual costs of implementing the work. Much of the management is done as part of economic agricultural activities, which can lower the actual net costs. One should also be aware of the amount of money that was already spent on the conservation of Aquatic Warblers and their habitat from 2001 until 2011, which was estimated during the same exercise: in these ten years, together 27 to 39 million US Dollar were already spent on Aquatic Warbler conservation, starting with only 700,000-1,200,000 in 2001 and increasing to 7,500,000-9,000,000 US Dollar in 2011. Over all the ten years, this was already about 10% of the estimated funds needed to push the species into the next lower red list category. Just taking the figures of 2011, this level of spending would already ensure 20-35% of the funds needed every year during the first ten years.

To get a better idea of where funds for Aquatic Warbler conservation come from, we can look at the example of the year 2011: almost 8 million US Dollar spent on Aquatic Warbler conservation were identified for this particular year. 4.2 million alone were contributed by the dedicated Polish agri-environmental scheme (see **Box 5.4**), supporting suitable management on about 7,000 ha of Aquatic Warbler habitat. 3.7 million were provided through large conservation projects, especially by three EU LIFE projects running in parallel during 2005-2015 – two in Poland and one in Lithuania (see **Table 5.1**). Almost 60,000 US Dollar were provided by national governments to finance two national coordinators for Aquatic Warbler conservation (Poland and France), and the Bonn Convention (CMS) to co-finance the employment of an International Aquatic Warbler Conservation Officer with the task to support the implementation of the International Memorandum of Understanding (MoU) for the Conservation of the Aquatic Warbler that was agreed in 2003 under the auspices of the Bonn Convention (see **Box 5.1**). Some 24,000 US Dollar were raised and spent by the Bird-Life International Aquatic Warbler Conservation Team (AWCT) on research and monitoring. Not included in these figures is any income generated by land managers through the use or sale of the biomass harvested from Aquatic Warbler sites.

Most likely, the Aquatic Warbler was one of the more expensive species considered in this exercise. The reason is simple: To move a species from 'vulnerable' to 'near threatened' involves a much larger population and much larger areas than saving the last dozens of birds of a critically endangered species to ensure the species can be downgraded to 'Endangered'. At the same time, improving the conservation status of Aquatic Warblers will have a much larger, landscape-scale effect and will ensure also the survival of a specific habitat type and its biological diversity. When talking about the costs of conserving Aquatic Warblers, then they already include the majority of costs for the management of a number of important national parks and nature reserves, such as the Biebrza National Park in Poland or the Zvaniec Mire Nature Reserve in Belarus. Of course, the calculation could also be done the other way around: by calculating the costs for running all nature reserves first. As this would cover most of the Aquatic Warbler population and their needs, then additional dedicated funding for the species would be only very small and only refer to the few occupied sites outside protected areas.

▲ **Fig. 5.3**

First issue of the Aquatic Warbler Flyway Newsletter, edited by the International Aquatic Warbler Conservation Officer under the Aquatic Warbler MoU (CMS, 2005).

▼ **Fig. 5.4**

Evening reception at the 1st Meeting of Signatories of the CMS Aquatic Warbler MoU, Criewen, Germany, June 2006 (photo: CMS).

Box 5.1

The international institutional umbrella for Aquatic Warbler conservation

LARS LACHMANN, ULADZIMIR MALASHEVICH & MARTIN FLADE

The Aquatic Warbler is unique amongst passerine birds for having its own international conservation agreement. The special attention it receives is understandable when considering that it is the rarest and most threatened migratory songbird of Europe and at the same time a flagship species for a threatened habitat type whose protection is pivotal not only for the conservation of biodiversity but also in the context of climate change and greenhouse gas emissions.

In 2003, a 'Memorandum of Understanding concerning Conservation Measures for the Aquatic Warbler' (Aquatic Warbler MoU) was signed during a meeting of range state representatives in Minsk, Belarus (**Fig. 5.3**). It forms a sub-agreement under the 'Bonn Convention' on the Conservation of Migratory Species of Wild Animals (CMS) and therefore has the same formal status as the better known African-Eurasian Waterbird Agreement (AEWA). The MoU currently officially recognises 22 countries as range states of the species during breeding, migration, or wintering. 16 of them, including all the key range states, as well as the CMS Secretariat and BirdLife International are signatories of the agreement.

All signatories pledge to implement conservation measures for the species as outlined in the International Aquatic Warbler Species Action Plan (SAP) that forms an integral annex to the MoU. Each country reports its progress against the measures outlined in the SAP in conjunction with regular meetings of the signatory parties of the agreement. To date, three of these meetings have taken place: 2006 in Germany (**Fig. 5.4**), 2010 in Poland (**Fig. 5.5**), and 2015 in Lithuania.

The AWCT acts as an informal scientific advisory body to the MoU. The secretariat of the Bonn Convention is supported in its role to oversee the coordination and implementation of the MoU by a specially employed to this end International Aquatic Warbler Conservation Officer, funded to date by the RSPB (BirdLife in the UK) and the CMS ►

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Box 5.1 contd Secretariat. The MoU forms an important political umbrella for the international cooperation between range states to protect its target species and facilitates funding from more affluent range states for actions to be undertaken in other countries important for the species.

The first version of the Aquatic Warbler SAP was published in 1996 as an EU Action Plan (Heredia et al. 1996). A revised version of it was prepared in 1998 and formed the original annex to the MoU. This action plan underwent two formal implementation reviews in 2004 and 2008, where a significant improvement in progress with the implementation of the proposed measures could be found (BirdLife International 2008). Following the 2008 review, a revised version of the action plan was produced (Flade & Lachmann 2008) and adopted as EU Action Plan, and in 2010 also adopted as the relevant action plan for the CMS Aquatic Warbler MoU. The meeting of signatory parties of the MoU introduced some minor updates to the plan in 2015, including the recommendation to also consider the additional use of ex-situ conservation measures to support declining marginal subpopulations of the species or to speed up the extension of its area of occupancy (AOO). The short-term objective of the plan is to maintain the size of all existing subpopulations, while the medium to long-term target is to increase the AOO to over 1,500 km^2 and achieve a 20% population increase compared to 2008 numbers. Any conservation projects for the species will refer to the SAP to justify the measures planned. At the same time, it provides sound guidance for interested funders.

▲ **Fig. 5.5**
Jarosław Krogulec, the representative of Poland as the host country chairing the 2nd Meeting of Signatories of the Aquatic Warbler MoU, and Marco Barbieri, CMS Agreements Officer, Goniądz, Poland, May 2010 (photo: L. Lachmann).

Sources of funding

Similarly to the conservation tasks to be financed, the available funding streams for Aquatic Warbler conservation are very diverse. While large amounts of money are important to finance habitat management on a landscape scale, even very small sources of money can have major important effects, as they can often be used very flexibly to support small key pieces of work that otherwise cannot be funded.

The AWCT, a loose but very effective group of species experts and conservationists, has been catalysing conservation work across the species' breeding, migratory, and wintering range by making strategic use of this kind of small-scale support, as portrayed in **Box 5.2**.

Unpaid volunteer effort has been very important to bring Aquatic Warbler conservation forward and still today enables the coordination of the work and the development of new conservation initiatives. Small-scale funding in the range of several thousand Euro has often been provided by national partners of BirdLife International to enable knowledge exchange, distinct pieces of research, and the development of larger projects. Especially concrete research projects have often benefited from funding by private conservation foundations or small research grants.

The contribution of annual government budgets to the conservation of the species

Box 5.2
The BirdLife International Aquatic Warbler Conservation Team: big footprint with small money
LARS LACHMANN & ULADZIMIR MALASHEVICH

Founded in 1998 in Brodowin, Germany, the BirdLife International Aquatic Warbler Conservation Team (AWCT) is an informal expert group of scientists and conservationists dedicated to the research and conservation of the Aquatic Warbler (**Fig. 5.6**).

The AWCT acts under the auspices of BirdLife International and includes over 50 members from all the breeding and most non-breeding range states of the species. It is chaired by Martin Flade of the State Office for Environment in Brandenburg, Germany (**Fig. 5.7**). The role of the AWCT is to facilitate information exchange, develop conservation strategies, coordinate population monitoring and research programmes, and to catalyse the development of new conservation initiatives. It also acts as a scientific advisory body to the International Memorandum of Understanding (MoU) concerning conservation measures for the Aquatic Warbler that has been agreed under the Bonn Convention in 2003 and has since been ratified by most range states. The main channels of communication are an e-mail distribution list and the AWCT website, currently hosted by the Polish Society for the Protection of Birds, OTOP (www.otop.org.pl).

The AWCT normally meets at least once a year, often as part of a field research programme or at the occasion of project events of ma- ►

► **Fig. 5.6**
A picture of the early days of the AWCT, near the Chełm Marshes, Poland, May 2002 (photo: Archive AWCT).

▼ **Fig. 5.7**
(top) Martin Flade, chairman of the AWCT, inspecting the effects of experimental summer mowing of a commercial reedbed, Rozwarowo, Poland, July 2011 (photo: L. Lachmann).

▼ **Fig. 5.8**
(bottom) Two grey eminences of the AWCT: Prof. Andrzej Dyrcz from Poland (left) and Dr Alexander Kozulin from Belarus (right), the godfathers of Aquatic Warbler research in their countries, Ławki Mire, Poland, August 2007 (photo: L. Lachmann).

Box 5.2 contd jor Aquatic Warbler conservation projects. The AWCT has to be credited for exploring the extent of the breeding distribution of the Aquatic Warbler and setting up regular population monitoring in most breeding range states (see Chapter 2.2), as well as identifying the African wintering grounds of the species, which had remained something of an enigma until 2007, when the AWCT confirmed the first major wintering site in Senegal (see Chapter 2.10). It has been involved in the analysis of genetic samples to identify the gene flow between Aquatic Warbler subpopulations and has recently employed geolocators to find out more about migration routes and wintering areas (see Chapters 2.9 and 2.10). Much of the basic science behind conservation activities undertaken or supported by AWCT was initiated by its two members, Prof. Andrzej Dyrcz in Poland and Dr Alexander Kozulin in Belarus (**Fig. 5.8**).

All this crucial work has been done with minimal financial resources. The AWCT received small scale annual financial support from the RSPB (the UK partner of BirdLife International) until 2017. This support is being continued since 2018 by NABU (the German partner of BirdLife International). Still, much of the work has been done by AWCT members at their own expenses and using their volunteer time. Additionally, the AWCT has been successful in securing numerous small grants for concrete pieces of research from a wide range of institutions and private foundations. These small grants could often be obtained on a short notice and therefore be used rather flexibly to support urgent work, and have therefore been a very valuable complement to large multi-year projects implemented by other organisations.

and its habitat is typically rather limited. The conservation budgets available in the regular budgets are normally not sufficient to finance habitat restoration or recurring management on a larger scale even within designated nature reserves or national parks. Normally, available funds are just enough to finance the running of the reserve administration and the salaries of the employees, and only include a small operation budget. Still, these funds are invaluable to provide necessary staff resources and provide funds for the planning and coordination of conservation action, and communication and outreach activities.They also provide an important source of co-funding for large externally funded projects.

For distinct large pieces of work, for the development and implementation of new conservation approaches, and for one-off restoration work externally funded projects are the most suitable source of funding. They can often provide large amounts of money and achieve a lot within a short time, but are always time-bound and will typically end after two to five years. They are therefore not a suitable funding source for ongoing recurring management needs.

Exactly this type of recurring management is typically being supported through incentive payments provided within the framework of the EU's agricultural policy, available in EU member states. This link to agricultural payments is often the cause of difficulties in the details and the practical implementation of such payment schemes. But there are perspectives that similar regular payments for recurring management may in the future be provided primarily as conservation payments rather than as agricultural payments.

The development and implementation of different types of economic activities that are in line with the requirements of Aquatic Warbler conservation has been an important element of many conservation projects, with the aim of providing funding for ongoing management after the end of the respective projects. Some of these economic activities are now being implemented and can finance parts of the costs of recurring management. However, so far, none of them is potent enough to create sufficient funds to fully finance the necessary management. Besides the traditional use of hay for fodder and bedding, an emerging line of activity is the use of biomass from Aquatic Warbler sites as climate-friendly heating fuel. The potential of fen mires for reducing greenhouse gas emissions also provides the opportunity to finance the restoration of peatlands through the sale of carbon credits set up for the achievement of international climate change mitigation targets. The practical implementation of this concept is, however, still very much in an early pilot phase. Last but not least, ecotourism has a role to play as a contribution to conservation funding and especially as an important argument justifying efforts to protect the Aquatic Warbler as flagship species of a very special habitat.This chapter will further provide more detail on all of these funding options.

Project funding

The foundation of the AWCT in 1998 along with the discovery of the hitherto unknown large Belarusian and Ukrainian subpopulations of Aquatic Warblers (see Chapter 2.2 and **Box 3.1**) served as a starting point for a growing number of research and conservation projects focusing on the Aquatic Warbler and the sites where it occurs. The number of small projects supporting distinct pieces of work is innumerable by now. They have played an important role in providing rather flexible funding for urgent activities on a comparably short notice. But increasingly, conservation organisations dedicated to the conservation of Aquatic Warblers and their habitat have also been able to attract funding for large projects.

Such large projects have been tremendously important to bring decisive advancement to the protection of most key breeding sites of the species, to develop new and improved conservation approaches, and – especially important – to develop and implement strategies that would enable the continuation of conservation actions beyond the end of the projects themselves. They have also been invaluable in building the capacity of the organisations running the projects, such as the BirdLife partner organisations in Belarus (APB) and Poland (OTOP). For both these organisations, Aquatic Warbler conservation projects were the first big projects they implemented. With the experience of these projects, they were fit to take on many more multi-million Euro conservation projects and make a real difference in nature conservation.

The range of the species stretches over a large geographical area (see Chapters 2.2, 2.9, and 2.10), with different project funding streams available. With the EU being one of the most important donors, the location of range states makes a big difference. The breeding range is divided between countries inside the EU – at least since the accession in 2004 – and those along its eastern borders (Belarus and Ukraine). Parts of the migratory range are still covered by the EU and one country (Morocco) neighbours the EU from the South. But the wintering range states in West-Africa do not have close geographical links to the EU. For countries within the EU, European funding mechanisms like the EU LIFE programme or EU Structural Funds, including contributions of the EEA-countries Norway, Switzerland, Iceland, and Liechtenstein are available. For countries along the eastern and southern borders of the EU, special EU Neighbourhood programmes are available, with other countries only able to benefit from global EU funding lines.

The global UN Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC) have led to the development of several international funding mechanisms that also focus on biodiversity and habitat conservation, such as the Global Environmental Facility (GEF) or various new funding streams under the UN Climate Convention. But also the EU and some national states are now offering funding programmes to contribute to the implementation of these conventions, such as the International Climate Initiative (ICI) and the European Climate Initiative (EUKI) of the German government.

All these major funding lines can be used to contribute to Aquatic Warbler conservation. Usually, however, conservation projects will have to be designed and shaped to meet the funding priorities of the different programmes, and the focus of projects may sometimes be the actual conservation of the species, but sometimes the protection of sites, climate mitigation, or the promotion of local livelihoods. All these aspects can often be very well combined with the needs of the species and its fen mire habitat.

The following section will provide an overview of some projects and funding lines that have been important to bring Aquatic Warbler conservation forward – without claiming that this would be a complete list of major projects.

First major projects in Belarus

Not long after the occurrence of Aquatic Warblers in Belarus had been discovered and shown to be the largest national subpopulation in the world (see **Box 3.1**), the Belarusian BirdLife partner APB and the RSPB (BirdLife partner in the UK) received project support from the Darwin Initiative, the UK government's instrument to support biodiversity conservation glob-

▼ **Fig. 5.9**
Alexander Kozulin and Viktar Fenchuk of APB (BirdLife Belarus) inspecting a water retention dike built to retain water in the main ditch surrounding the Zvaniec Mire, Belarus, November 2004 (photo: L. Lachmann).

ally to fulfil its commitments under the CBD convention. Thanks to a Darwin grant of about 160,000 Euro and additional co-financing, the project 'Management Planning for Conservation of Fen Mire Biodiversity in Belarus' could be implemented from 1999 to 2002 with a total budget of 250,000 Euro. During this time, concise management plans could be developed and approved for the three most important Aquatic Warbler breeding sites in Belarus, the fen mires Zvaniec, Sporava, and Dzikoje, together holding about half the world's breeding population of the species at that time.

This project was swiftly followed by another project with a total budget of 310,000 Euro, supported by the Darwin Initiative and supplemented by the private German Michael Otto Foundation and other co-funders. It ran from 2003 to 2006. Its aim was to implement the most urgent conservation measures agreed in the management plans developed within the preceding project. This meant primarily the stabilisation of the hydrology of the sites that had been badly affected by drainage (**Fig. 5.9**) of the surrounding areas and by irregular off-charge of water from a fish farm upstream of the Aquatic Warbler sites at Sporava. Additionally, both Zvaniec and Sporava mires were declared national nature reserves and received their own administrations. This way, less than ten years after machinery was standing ready to embark on the drainage and removal of peat from the Zvaniec Mire (**Fig. 5.10**), the two most important Aquatic Warbler sites in the country had been secured and designated specifically for the protection of the Aquatic Warbler, a species that had gained some prominence in Belarus by the end of this project (see also Chapter 7). Today, Darwin Initiative grants are not available any more for European countries, but remain a viable funding option for range states in Africa.

In the meantime, APB worked with the RSPB, the national office of the United Nations Development Programme (UNDP), and the Belarusian Ministry of Environment to develop a series of projects to be funded under GEF. GEF was established on the eve of the 1992 Rio Earth Summit to help tackle our planet's most pressing environmental problems. It is an international funding mechanism to support the implementation of the UN's environmental conventions, amongst them the CBD and the climate convention UNFCCC, in developing countries. It is implemented through a number of international organisations, such as the UNDP. It typically provides very large project grants, but requires a strong buy-in and co-financing of national governments, with NGOs normally being junior partners in the projects. Two such GEF projects started in Belarus around the year 2005. One focused on the conservation of the wetlands of the Prypiac Valley in southern Belarus, including the Zvaniec Mire (GEF 'Polesie' project). The other project, dubbed 'GEF Peatlands project' provided the first big leap in the development of the Belarusian programme for the restoration and rewetting of peatlands, with over 21,000 ha of peatlands saved from further degradation and rewetted (Kozulin 2011). At the time of writing, the Belarusian government is implementing a project called 'GEF Peatlands 2'. The peatlands covered by these projects are not expected to become immediately suitable for Aquatic Warblers, but they are an investment into the future

▼ **Fig. 5.10**
Peat extraction on drained mire in Belarus, July 2005. The Zvaniec Mire, holding the largest number of Aquatic Warblers in the world only narrowly escaped this fate in the mid-1990s, when the Aquatic Warbler was discovered there (photo: L. Lachmann).

and some of them are assumed to become attractive to the species once natural mire vegetation has re-established itself – a matter of several decades.

In 2004, ten countries joined the European Union, among them Lithuania, Poland, and Hungary as breeding range states of the Aquatic Warbler. For the first time, a sizeable proportion of this species' world population could be found within the borders of the EU, where its occurrence until then had been restricted to the last remnant birds in Germany near the Polish border. Similar to Belarus, the Aquatic Warbler was clearly the highest bird conservation priority for Poland considering its globally threatened status and the high proportion of the world population that lives in each of these countries. Therefore, it is not surprising that OTOP (BirdLife partner in Poland) soon embarked on using EU funding to protect the species.

EU LIFE programme

Within the EU, the LIFE programme is the only funding instrument dedicated exclusively to the environment. It has always been divided into two strands: LIFE Nature and Biodiversity, supporting classic species and site conservation work and LIFE Environment, focusing especially on the non-biotic environment, such as air, soil, waste, or chemicals. Later, an additional strand called LIFE Communication was added, and since 2014 another strand has operated, called LIFE Climate Action. The LIFE programme is intended to help achieve the EU's environmental goals. Therefore, LIFE funding is usually only available for member states of the EU. But recent amendments to the LIFE rules allow also spending LIFE funding in countries outside the EU, if this is necessary for the effectiveness of interventions carried out in member states and contributes to achieving EU conservation goals.

Aquatic Warbler conservation appears to be a classic case, where conservation action improving breeding conditions for the species along the eastern borders of the EU in Ukraine and Belarus contributes to the protection of birds in Poland and Lithuania that form part of the same sub-populations. Equally, conservation action along the migratory route in Morocco or Mauretania, or in the wintering sites in

▼ **Table 5.1**
The list of projects funded under the EU LIFE programme, that have targeted Aquatic Warbler conservation.

Project title	Project reference	Duration	Country	Beneficiary	Total budget in Euro	LIFE contribution in Euro
Carricerín Nava-Campos – Conservation of the aquatic warbler in the ZEPA 'La Nava-Campos'	LIFE02 NAT/E/008616	2002-2006	ES	Junta de Castilla Leon / Fundacion Global Nature	1,217,240	912,930
Acrocephalus Bretagne – Conservation of the Aquatic Warbler in Brittany	LIFE04 NAT/FR/000086	2004-2009	FR	Bretagne Vivante	965,139	723,854
Aquatic Warbler project – Conserving *Acrocephalus paludicola* in Poland and Germany	LIFE05 NAT/PL/000101	2005-2011	PL / DE	OTOP (BirdLife Poland)	5,457,109	4,092,832
Facilitating Aquatic Warbler (*Acrocephalus paludicola*) habitat management through sustainable systems of biomass use	LIFE09 NAT/PL/000260	2010-2015	PL	OTOP (BirdLife Poland)	3,686,306	2,730,471
Baltic Aquatic Warbler - Securing Sustainable Farming to Ensure Conservation of Globally Threatened Bird Species in Agrarian Landscape	LIFE09 NAT/LT/000233	2010-2015	LT	Baltic Environmental Forum	2,191,685	1,636,666
LIFE MagniDucatusAcrola – Stepping stones towards ensuring long-term favourable conservation status of Aquatic Warbler in Lithuania	LIFE15 NAT/LT/001024	2016-2023	LT	Baltic Environmental Forum	4,097,038	3,072,778
LIFE PALUDICOLA – Habitat restoration for the Spring and Autumn migration of the Aquatic Warbler in the Iberian Peninsula	LIFE16 NAT/ES/000168	2017-2020	ES	Fundación Global Nature	1,550,968	1,163,226

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Senegal or Mali will obviously contribute to achieving the EU goals of maintaining and increasing the Aquatic Warbler population. And indeed, there already is a first LIFE project focusing on Aquatic Warblers in Lithuania that includes activities in neighbouring Belarus (see **Table 5.1**).

LIFE was established in 1992 and is managed by the European Commission. Since then it has co-financed over 4,500 projects across the EU. The current LIFE programme for the period 2014-2020 has a budget of about 3.4 billion Euro. Between 1992 and 2013, more than 370 LIFE Nature projects carried out restoration actions on peatlands, most of them – directly or indirectly – also targeting the restoration of fen mires. LIFE projects have pioneered a range of techniques for the effective and stable restoration of bogs and fens (European Commission 2015).

The Aquatic Warbler is listed by the LIFE programme as a 'priority species'. This means that projects focusing on this species will benefit from an increased LIFE co-funding rate of 75% as opposed to the original 50%, now 60%, for projects on other species. As intended, this rule has increased the number of projects targeting this species. So far, five LIFE projects related specifically to the Aquatic Warbler and the sites where it occurs have been implemented, and two are currently running (**Table 5.1**). The combined budget of these projects amounts to c. 19.2 million Euro, of which the LIFE contribution is c. 14.3 million Euro.

A number of additional projects, not listed in **Table 5.1**, quote the Aquatic Warbler as one of their several target species. One of them is the German project on the Lesser Spotted Eagle, which also targets potential Aquatic Warbler habitats ('LIFE Schreiadler Schorfheide-Chorin', duration 2012-2019). In this project, very valuable experience with top soil removal as peatland restoration measure was gained (see **Box 4.7.2**).

Due to the fact that the breeding range of the Aquatic Warbler was basically located outside the EU until 2004, the first Aquatic Warbler LIFE projects were implemented in Spain and in France, focusing on important migratory stopover sites. These projects initiated intensive research into the migratory behaviour of the species and ensured the conservation of good habitats at key sites. They are described in more detail in **Box 2.9.2**. As with all Aquatic Warbler LIFE projects to date, the advisory body meetings, scientific workshops, and conferences that typically form part of LIFE projects have facilitated the exchange of experience between scientists and conservationists working on the species, spawned initiatives for the development of

▼ **Fig. 5.11**
Participants of the project planning workshop for the first Polish Aquatic Warbler LIFE project, Międzyzdroje, Poland, February 2004 (photo: OTOP).

► **Fig. 5.12**
Acknowledging the donor is part of implementing a LIFE project, and ironing is always best done from the back side of the tissue, Aquatic Warbler LIFE project, Marki near Warsaw, Poland, April 2008 (photo: L. Lachmann).

new projects and have usually doubled up as meetings of the AWCT.

The project that OTOP developed in 2005 with support of the RSPB was called 'Aquatic Warbler project – Conserving *Acrocephalus paludicola* in Poland and Germany' (**Fig. 5.11**, **5.12**). Its aim was to save the critically endangered Pomeranian subpopulation of the species along the German-Polish border from extinction and to increase and improve the area of suitable habitat for the species in the Biebrza Valley in northeastern Poland, the most important breeding site of the species in the country. This project has shown that habitat management for the Aquatic Warbler is possible even on a landscape scale. Research and experience gained during its implementation and the initiatives and activities that it facilitated have informed much of the content of this book. **Box 5.3** presents a more detailed insight into the achievements of this project.

The first Polish Aquatic Warbler LIFE project has identified the economic use of biomass as climate-friendly fuel as a tool to support the ongoing management of habitats suitable for the species. Importantly, today there is almost no demand for the traditional use of fen mire biomass as fodder or bedding for livestock. At the same time, large amounts of unused biomass resulting from the large-scale implementation of the recently introduced Polish agri-environment schemes for Aquatic Warblers created a practical problem that needed solutions.

To link the production of biomass as a renewable energy source with the large-scale mechanised management of Aquatic Warbler habitat, OTOP developed and received funding for a second LIFE project, addressing this aspect. The project 'Facilitating Aquatic Warbler habitat management through sustainable systems of biomass use' (see **Table 5.1**) was carried out in Aquatic Warbler sites in northeastern and southeastern Poland, covering about 80% of the Polish subpopulation of the species.

Within the project, the utilisation of biomass from all project sites could be arranged. Where available, bales of biomass

Box 5.3

The Polish Aquatic Warbler LIFE project 2005-2011

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The project (see also **Table 5.1**) aimed to prevent the extinction of the Pomeranian subpopulation and to increase and improve the area of available habitat in the Biebrza Valley. It has brought about a number of achievements that have brightened up the prospects for the conservation of the Aquatic Warbler and its specific fen mire habitat:

- The exact breeding habitat and conservation requirements of the Aquatic Warbler and its reaction to conservation measures are now known in more detail.
- A new management technology has been introduced to enable large-scale mechanised mowing on delicate wet peat soils. The new harvesters are adjusted alpine piste-bashers on caterpillars with very low ground pressure, able to mow large areas of Aquatic Warbler habitat with minimal impact on the ground (see Chapter 4.4).
- Active conservation management was implemented or enabled on over 8,000 ha within nine project sites, which are now under regular maintenance management.
- The project has arranged for financial support to be given for Aquatic Warbler friendly land management in Poland through agri-environmental schemes, therefore enabling the continuation of the project work and the manifestation of its achievements for a long period beyond the project.
- The project has made almost 1,000 ha of land available for active conservation work through the purchase of land and the establishment of new private nature reserves for the conservation of the Aquatic Warbler.
- In order to ensure the ongoing management in the long term, even beyond the potential end of agri-environmental support, the project developed and advanced concepts for the use of biomass arising from habitat management as carbon-neutral heating fuel, which were implemented, for instance, in a follow-up LIFE project.

Aquatic Warblers have reacted positively to the changes brought about by the project, with the Pomeranian subpopulation still in existence and the speed of decline slowed down from 12% annually between 1993 and 2003 to only 4% annually between 2003 and 2011 (see also Chapter 2.2). Much more suitable habitat for the species is now available in Pomerania (Tanneberger et al. 2014), but numbers were critically low at just over 50 singing males at only six remaining sites at the end of the project. The picture appeared rosier at the Biebrza Valley, where the overall subpopulation of Aquatic Warblers remained stable, while numbers increased by 20% between 2005 and 2010 where LIFE Project management was implemented. Altogether, 336 ha of restored habitat had been re-occupied by the species in the areas managed by the project.

Numbers are also very promising for the new OTOP reserves purchased within this project in the buffer zone of the Biebrza National Park. Between 2005 and 2011, numbers of singing males increased from five to 21 in one site (Ławki-Szorce) and from 25 to 128 in another (Mścichy). ►

Box 5.3 contd Besides the beneficial effects on the Aquatic Warbler, the most notable result of the large-scale management was the return of large numbers of meadow breeding waders to the mown areas, especially in the Biebrza National Park.

A special strength of the project was that it ensured the legacy of the landscape-scale change beyond its duration, through a strong emphasis to develop and ensure sustainable financing mechanisms for recurring conservation management.

▲ **Fig. 5.13** **Briquetting facility of the Gogol family (company 'Carex', project partner in the LIFE biomass project) in Zaczerlany, Narew Valley, Poland, June 2008** (photo: L. Lachmann).

were sold to existing facilities in the surroundings, where biomass briquettes or pellets have been produced (**Fig. 5.13**). A cement factory near the town of Chełm used whole bales to supplement its fuel for the cement burning oven. In the Biebrza Valley, where the largest areas are being managed, nearby biomass facilities did not exist. Therefore, OTOP set up a pellet production line in the village of Trzcianne (see **Box 5.6**). One of the main findings of the project was – as discussed also below – that the use of biomass for energy production can reduce the net costs of habitat management but under current circumstances – given the prices of fossil fuels and their carbon-neutral alternatives – is not able to fully cover the costs of habitat management.

Therefore, it proved very important that the project and the results of the monitoring and research work (e.g. Kubacka et al. 2014, Kloskowski et al. 2015) implemented in its course managed to influence the design of the second phase of the Polish agri-environmental scheme package for the Aquatic Warbler. These improved schemes now allow the implementation of tailor-made conservation management for the different sites where the species occurs (see **Box 5.4**).

The project also succeeded in enlarging the area of the sites covered by recurring land management favourable to the target species from c. 1,500 ha to over 6,000 ha. This habitat restoration was mostly achieved by tree and bush removal and first time mowing. As a result, over the five years of the project's duration the area occupied by Aquatic Warblers within the project sites had increased from 3,600 ha to 3,900 ha – almost an 8% increase, while the number of singing males in the project priority areas had increased by more than 25% (575 singing males).

Besides Poland, the only other EU member state with a significant breeding subpopulation of Aquatic Warblers is Lithuania (see Chapter 2.2). Encouraged by the Polish example, a consortium of partners led by the Baltic Environmental Forum (BEF) obtained funding for a Lithuanian LIFE project on the species in 2010. The Project 'Baltic Aquatic Warbler – Securing Sustainable Farming to Ensure Conservation of Globally Threated Bird Species in Agrarian Landscapes' (see **Table 5.1**) managed to turn around the decline of the remaining Lithuanian subpopulation that is concentrated in a few sites within the delta of the Nemunas river. Most of the Aquatic Warblers in the delta area occur on eutrophic wet meadows that are still rather intensively used for agriculture and in fact depend on rather intensive land use to remain suitable for the species, while at the same time early mowing causes the loss of broods (see Chapter 4.4). Thus, the project had to put particular emphasis on developing conservation mechanisms that work with farmers and on agriculturally used land (see Chapter 7).

The key achievement of this project was the development of a specialised and very targeted agri-environmental scheme for the Aquatic Warbler in Lithuania. In the eutrophic wet meadows, this involves a close monitoring of Aquatic Warbler occurrence leading to the decisions whether a certain plot of land should be mown early (when no birds are present) or late (when Aquatic Warblers are breeding). This scheme found acceptance among the local farmers and could be introduced as an official scheme in 2015 (see **Box 5.5**).

The restoration of degraded Aquatic Warbler habitats through first-time management also formed an important part of the project. Over 1,400 ha of habitat could be restored and prepared for ongoing management to be financed by the new agri-environmental schemes. Besides mowing and bush removal, also controlled burning was pioneered as a restoration and management technique (see also Chapter 4.6). As in Poland, new machinery suitable for the habitat management on very wet ground was introduced, and a biomass pelleting facility was set up at the Žuvintas Biosphere Reserve (**Fig. 5.14**). The success of the project was proven by the positive development of the national Aquatic Warbler subpopulation: after a low point of only 50 singing males in 2013, numbers increased to over 140 in 2015 (see Chapter 2.2).

As in Poland, it was felt that after the first LIFE project still more had to be done to ensure a safe future for the Lithuanian subpopulation of the Aquatic Warbler. Of particular concern is the fact that the subpopulation in the Nemunas Delta near the shores of the Baltic Sea appears to be isolated from the next closest breeding sites in the Biebrza Valley of Poland and sites in northern Belarus (although genetic isolation has not yet been shown). To tackle this threat, BEF and its consortium embarked on a second LIFE project, 'LIFE MagniDucatusAcrola – Stepping stones towards ensuring long-term favourable conservation status of Aquatic warbler in Lithuania' (see **Table 5.1**).

▲ **Fig. 5.14**
Pelleting facility at the Žuvintas Biosphere Reserve (photo: Ž. Morkvėnas).

The main aim of the project is to restore degraded habitats in Lithuania as well as in parts of Belarus, to provide a chain of suitable habitat linking currently occupied breeding sites. A special focus of the project is given to the Žuvintas Biosphere Reserve, where thanks to the previous LIFE project, the first Aquatic Warblers have recently returned to breed, thus forming the only occupied site between Belarus, Poland, and the Nemunas Delta. As the situation of the species in Belarus is decisive for the success of the project, this project has for the first time managed to obtain LIFE funding for Aquatic Warbler conservation outside the borders of the EU. Besides all important sites for the species in Lithuania, the project is also covering the largest (Zvaniec Mire) and the northernmost (Servač Mire) as well as an important potential (Dakudauskaje) breeding site in Belarus to ensure a healthy source subpopulation and suitable stepping stone sites necessary to re-establish the connectivity between the subpopulations of the two countries.

The project will apply traditional restoration methods for the target habitats, such as elimination of reeds and removal of bushes. An innovation will be the application of an accelerated method of seeding sedge vegetation. A biomass processing facility will be set up in the Nemunas Delta area.

Most notably, the project also aims to carry out the first translocation of Aquatic Warblers: 100 recently fledged Aquatic Warblers are planned to be transported from the Zvaniec Mire in Belarus to the Žuvintas Biosphere Reserve in Lithuania. A return rate of 40% to the release site is expected and would be considered a success. The effectiveness of the species translocation will be a key topic at expert meetings and the project's closing conference. If successful, it is expected that further Aquatic Warbler translocations could be used to support remnant subpopulations in western Poland or to reestablish new breeding sites in suitable habitats in Poland, Hungary, or Germany.

European Structural Funds and EEA contributions

While the EU's LIFE programme is the only EU funding stream specifically targeted at environmental issues, it is very small compared to other EU financing mechanisms and makes up only 0.35% of the overall EU budget. A much larger share of the EU budget (c. 30%) is expended by the EU Structural and Cohesion Funds. Their main aim is to reduce the disparities in living conditions between different parts of the EU. Therefore, only those parts of the EU whose living standards are below a certain average level are eligible for funding from this source. Simply speaking, this means that the new eastern member states are eligible while wealthier countries of the old member states are not. Hence, all the EU breeding range states of the species apart from Germany are in principle eligible.

What exactly will be supported by these funds is determined through the so-called operational programmes agreed between the EU Commission and the respective member states. In many cases, environmental issues and even the conservation of biodiversity are included as topics that can be supported under these operational programmes. This way, as an example, one of the programmes agreed for Poland is the 'Operational Programme for Infrastructure and the Environment' with a budget of 24 billion Euro for the budget period 2014-2020. Environmental protection and climate adaptation form one of its ten thematic strands. A special agency set up within the country's forest administration, the 'Coordination Centre for Environmental Projects' (CKPŚ) administers the implementation of this funding strand. Similar funding opportunities based on the EU structural and cohesion funds should be available also in Lithuania and Hungary.

OTOP has already implemented several conservation projects funded under this programme, typically with a total budget of around one million Euro. At the time of writing, a new project targeting the Aquatic Warbler subpopulation of the Lublin region in southeastern Poland has just been approved for funding ('Enhancing the southeastern metapopulation of Aquatic Warbler (*Acrocephalus paludicola*) in Poland', duration 2017-2020). The aim of the project is to facilitate the reoccupation of new breeding sites in the area away from the core sites in the Chełm Marshes and the Poleski National Park. The expansion of this regional metapopulation of Aquatic Warblers has been made possible after the LIFE biomass project (2010-2015) had managed to optimise the habitats in the core areas of the Lublin subpopulation and sparked a number of attempts of Aquatic Warblers to occupy new breeding sites in the area. Some 13 sites are planned to be prepared as potential stepping stone sites.

Four European countries are part of the European Economic Area, thus taking part in the European Single Market, but are not part of the EU. These are Iceland, Liechtenstein, Norway, and Switzerland. Part of the deal that allows them to be part of the single market is for them to contribute to the European Structural Funds. They do this by operating separate funding programmes, interchangeably called EEA grants, Norway funds or Swiss contribution.

Simply speaking, the countries eligible for the European Structural Funds are also eligible for these funding programmes. Each beneficiary state decides on specific programmes together with the donor countries. For the period 2014-2021, one of the priorities is environment, energy, climate change, and low carbon economy.

OTOP has implemented a project supported by the Swiss contribution aimed at monitoring the effectiveness of agri-environment schemes, including the Aquatic Warbler package. Previously, another OTOP project used Norway funds to implement a caretaker network and monitoring system for Poland's Important Bird Areas (IBAs), which include many sites designated as IBAs because of the occurrence of Aquatic Warblers.

Another example of an EEA grant used for the conservation of the Aquatic Warbler is the project 'Creation of mechanisms to secure good quality of open habitats in Nemunas Delta regional park', implemented by the Baltic Environmental Forum in Lithuania (duration 2014-2016, total budget 320,000 Euro). The project targeted the same complex of problems as the two Lithuania Aquatic Warbler LIFE projects. The project was mainly used to support farmers to implement the specific management needed on wet Aquatic Warbler habitat by purchasing suitable machinery for mowing and the transport of biomass.

EU Neighbourhood programmes and INTERREG

What the EU Structural Funds are for the less developed EU member states, the EU Neighbourhood Programme and the INTERREG programme are for countries along the outside borders of the EU. Their aim is to diminish the influence of national borders in favour of equal economic, social, and cultural development. Of the two programmes, INTERREG is more focused on cross-border cooperation between EU member states but also foresees the inclusion of countries outside the EU. The EU Neighbourhood programmes specifically target countries along the outside borders of the EU, such as Belarus, Ukraine, or Morocco, which are important in terms of Aquatic Warbler conservation. Projects under these programmes always need to have partners in several countries and need to involve cross-border cooperation. Similar to the EU Structural Funds, concrete funding priorities are subject to a programming approach implemented separately for each funding period and for each border region. Normally, the conservation of the environment features quite well in the programmes of these funds. Even though these funding programmes appear to be important opportunities to raise funds for the conservation of the important Aquatic Warbler breeding subpopulations in Belarus and Ukraine or of key stopover sites in Morocco, there has not yet been a successful application to these funds with a topic related to Aquatic Warblers. One attempt for a project involving the most important breeding sites in the border region of Poland, Belarus, and Ukraine has been unsuccessful.

Funding under UNFCCC and CBD commitments

Under the UNFCCC, developed countries have pledged to support less developed countries financially in their efforts to mitigate climate change and to adapt to their effects. As the conservation of fen mires as Aquatic Warbler habitats is intrinsically linked to their function as carbon storage and – if drained – source of greenhouse gases, funding streams targeting climate mitigation and adaptation can well be used to advance also the conservation of Aquatic Warblers.

The ICI is the funding programme of the German government to implement its commitments under the UNFCCC. It also covers commitments under the CBD and therefore has an additional emphasis on biodiversity protection. It has been in operation since 2008.

ICI has approved funding for two large peatland rewetting projects in Belarus and Ukraine. Unfortunately, only the Belarusian project could be fully implemented. The project 'Restoring Peatlands and Applying

▲ **Fig. 5.15** **Biomass production in the slightly eutrophic parts of the Zvaniec Mire is big, making it hard to progress through the sedge and reed vegetation, Belarus, July 2009** (photo: L. Lachmann).

Concepts for Sustainable Management in Belarus' (2008-2012) was awarded c. 3.2 million Euro and was implemented by the German Michael Succow Foundation and the RSPB (BirdLife partner in the UK) together with their Belarusian partners. The project built on experience gained in Belarus during the 'GEF Peatlands' project. Over 17,000 additional hectares of peatlands were rewetted and handed over to mire-adapted land management (Kozulin 2011). A key aim of the project was the development of a sustainable funding mechanism based on the sale of carbon credits (see below). The main outcomes of the project are presented in Tanneberger & Wichtmann (2011) and Chapter 4.7.

Another funding line under this general theme, albeit already almost completed, is 'ClimaEast'. It is a European Union funded project package assisting six Eastern Neighbourhood Partnership countries and Russia in approaches to climate change mitigation and adaptation. The package provided funding of 11 million Euro for one pilot project in each country that support the development of ecosystems-based approaches to climate change. These projects are implemented through UNDP.

The 'ClimaEast' pilot projects in Belarus and Ukraine tackle the issue of peatland restoration. The Belarusian project 'Conservation and sustainable management of peatlands in Belarus to minimize carbon emissions and help ecosystems to adapt to climate change, while contributing to the overall mitigation and adaptation effort' is especially worth noting as it focuses on Aquatic Warbler fen mires (duration 2014-2017, total budget 1.5 million Euro).

The project focuses on the two most important Aquatic Warbler breeding sites in the country, the Zvaniec Mire (**Fig. 5.15**) and the Sporava Mire, together holding more than 30% of the world population (see also Chapter 2.2). The activities of the project appear to be a natural continuation of the Darwin Initiative projects of the years 1999 to 2006 mentioned in the beginning of this chapter, now implementing the next step of measures foreseen in the management plans: appropriate vegetation management. For this overgrown areas of the mire have been cleared of bushes and reeds with newly acquired specialised machinery (see Chapter 4.3). Controlled burning was also used as an alternative method (see Chapter 4.6). The biomass harvested has been used as alternative fuel to replace fossil fuels. The hydrological system of the sites has been further improved (see Chapter 4.2) and the original management plans were revisited, updated, and approved including public consultation.

Future perspectives of project funding

The multitude of large projects on the conservation of the Aquatic Warbler described above shows that a single large project is far from enough in order to save a globally threatened bird species, but also that a lot of financing options exist to source the funds necessary to achieve the goal set out in the Aquatic Warbler Species Action Plan: to increase the area of occupancy to a level that justifies taking the species off the list of globally threatened species.

The selection of funding sources described above does not include national funding options that exist in many countries, such as the Mire Conservation Programmes of single German federal states (see Chapter 4.7) or the 'Large-scale Nature Conservation Project' facility, also in Germany. It also does not include private foundations that can potentially contribute substantial sums, as for example for a project aiming at creating new Aquatic Warbler breeding sites to connect the existing sites in Lithuania, Belarus, Ukraine, and Poland that is currently in the final stages of preparation by the respective national BirdLife partner organisations and is hoping to obtain near five million US Dollar from a private foundation.

The experience of the past two decades of Aquatic Warbler conservation has shown that often the limiting factor is not available project funding but rather the capacity of potential beneficiaries to apply for and implement meaningful projects. It also has appeared that the successful use of available funding streams in a strategic way by many different organisations needs a good level of coordination effort. This is where the strength of the Aquatic Warbler conservation framework lies: having the institutional umbrella of the CMS Aquatic Warbler MoU, the strategic guidance of the Aquatic Warbler SAP, the support of the International Aquatic Warbler Conservation Officer, and the scientific guidance and networking power of the AWCT has made a big impact and provides the necessary coordination function.

But still, project funding alone cannot provide all the funding that is needed to conserve the species. Projects, by their very nature, are always time-bound and aim at a certain defined achievement. They cannot provide permanent resources for recurring habitat management, which is necessary almost everywhere to maintain the habitats of Aquatic Warblers. The following sections will therefore look at funding streams that have the potential to permanently fund or contribute to the costs of ongoing habitat management.

Incentive payments

Traditionally, most Aquatic Warbler breeding sites have been subject to a very low-intensity form of agricultural use. This use has kept habitat conditions stable even though in most cases the underlying ecological factors, such as the water table or the nutrient content of the sites, have been changing (Chapters 4.1 and 4.4). Therefore, on most Aquatic Warbler sites today it is necessary to either maintain or imitate the traditional land use. Both alternatives would spell the end for Aquatic Warblers at these sites: intensification of land use as well as the complete abandonment of it (see also Chapter 3).

There are still sites across the breeding range where suitable extensive land use with low intensity mowing for livestock feed and bedding, or even sometimes low-intensity grazing still exist. This is the case in some parts of the Aquatic Warbler sites in Ukraine and possibly in small sections of the sites in Belarus. But in almost all other sites, there is either the danger of complete abandonment of any land use, especially within formally protected areas like the Biebrza National Park in Poland or the Zvaniec Nature Reserve in Belarus, or the danger of intensification through drainage and increased mowing intensity or early mowing dates. The latter is the case in most sites without strict nature protection, for instance those in the buffer zone of the Biebrza National Park, and on more eutrophic floodplain meadows like those in the German Oder Valley or the Nemunas Delta in Lithuania.

The International Species Action Plan for the Aquatic Warbler therefore sets a goal to ensure that "national and international policies and legislation necessary for the conservation of the Aquatic Warbler and its habitat are in place". One of the means to reach this goal is put forward in Action 1.5 of the Plan: "Seek national and international policies and financial incentives to promote suitable land management practices at sites whose sustainability depends on continued extensive land use." These incentives have been implemented in the EU breeding range states of Aquatic Warblers in the form of agri-environmental schemes (AES), Less Favoured Area payments, and Natura 2000 payments.

All these payments are part of the EU's Common Agricultural Policy (CAP), which currently makes up about 40% of the total EU budget with a total value of c. 60 billion

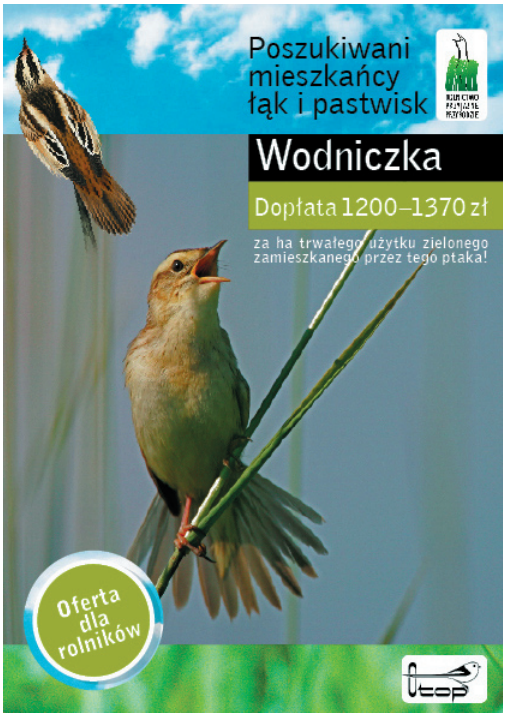
Euro per year. Only about 7.6% of this sum is invested in agri-environmental schemes. Most of those are very general low-level schemes, and only 2.3% of the overall CAP budget is spent on the so-called 'dark-green' agri-environmental schemes that spe-cifically address biodiversity issues.

However, in the context of Aquatic Warbler conservation, the most important factor to keep in mind is that within the current structure of the EU budget, all these payments are essentially agricultural payments, not payments to finance nature conservation. The only areas eligible for agri-environmental payments are plots that are officially registered as agricultural land. This leaves some areas, especially within nature reserves that have not been used for many years, in danger of not being eligible for such payments.

The definitions of agricultural land are handled very differently in the different member states. While in Poland it was enough to show that the land had historically been used agriculturally and to restore it to a state fit for the implementation of normal agricultural management, e.g. through the removal of bush and tree succession, in Germany a license system is being applied. In order to ensure that the agricultural area eligible for funding is controlled a system of certificates of eligibility that are being traded between land users has been set up. Another difference relevant to Aquatic Warbler conservation is the eligibility of commercial reedbeds that are typically harvested in mid-winter. Poland has accepted this to be eligible agricultural land, while Germany regards this type of land use as non-agricultural and it is therefore ineligible for agriculture funding.

The second limitation is that due to the logic of these agricultural schemes, payments cannot be made according to the expected outcome of the measures – like the creation of a certain habitat condition or of certain numbers of target birds – or be based on a competitive supply and demand calculation to ensure there will be enough uptake of the scheme to achieve the envisaged conservation gains. Instead, the level of support has to be calculated according to any agricultural income foregone or extra costs incurred by following the rules of a scheme. Only a very small incentive element can be added to these payments, so that these schemes are often only marginally more attractive than business as usual, but at the same time loaded with a lot of administration effort, so that many good schemes suffer from a lack of interest from the side of the farmers. Additionally, this calculation can be very difficult to do if the alternative agricultural use would be complete abandonment.

Poland has been at the forefront of implementing agri-environmental schemes relevant to the Aquatic Warbler, with its agri-environmental programme for the years 2007-2013 and the new agri-environmental and climate scheme (AECS) for the years 2014-2020 (see **Fig. 5.16** and **Box 5.4**). Both of these contain packages which target selected bird species breeding in wet grassland, including the Aquatic Warbler, first included in 2009. The schemes available in these two programmes have facilitated the re-introduction of Aquatic Warbler-friendly land use on large areas by providing attractive subsidies to land users in return for managing the land in line with specific



► **Fig. 5.16**
Title page of a leaflet promoting the first agri-environmental scheme for Aquatic Warblers in Poland, 2009 (design: OTOP)

requirements.

In Lithuania, appropriate schemes for the Aquatic Warbler became available in the following budget period. The agri-environmental programme for 2014-2020 (see **Box 5.5**) contains a targeted Aquatic Warbler scheme that has been available since 2015 and is considered a major achievement. Subsidies are granted to mown or grazed land, including wetlands. There is also an interesting option that allows restoration of degraded Aquatic Warbler habitats in a singular investment and must be followed by a switch to one of the Aquatic Warbler habitat maintenance packages.

Both in Poland and in Lithuania, the agri-environmental schemes are paid out on top of the CAP direct payments that are paid for every agricultural land, and can

Box 5.4

Aquatic Warbler packages in the Polish agri-environmental schemes

JUSTYNA KUBACKA

In the Polish Aquatic Warbler AES and AECS packages management is implemented through grazing, mowing, or both (**Table 5.2**). The requirements ensure a reduced frequency and delayed timing of mowing, or lower grazing intensity. The fixed requirements of each package set out in the AES of 2007-2013 evolved into more flexible rules of the AECS in the following funding period 2014-2020, tailored to groups of species. This change has been crucial, since the threats to the Aquatic Warbler and the management needs of the habitat are site-specific (see Chapter 3). Plots are qualified for a subsidy by a licensed expert on the basis of a field survey and a report. The key requirements, such as the timing and extent of mowing can be adjusted by the expert to local conditions within the ranges specified by the schemes. The AES/AECS package can be combined with other subsidies, which since 2015 have comprised: direct payment, including the greening component (in total 219 €/ha); and Less Favoured Areas payment (42 or 62 €/ha), as of 2015.

▼ **Table 5.2**

An overview of the Aquatic Warbler packages in the Polish agri-environmental schemes.

	AES 2007-2013	AECS 2014-2020
Name of package	4.1/5.1 Protection of bird breeding habitats	4.9 Protection of bird breeding habitats: Aquatic Warbler
Eligibility	permanent grassland with occurrence of the target species confirmed by a licensed expert	permanent grassland only within Natura 2000 areas with occurrence of the target species confirmed by a licensed expert
Payment	1,370 PLN/ha (312 Euro) within Natura 2000, 1,200 PLN/ha (273 Euro) otherwise	1,199 PLN/ha (273 Euro)
KEY REQUIREMENTS		
Mowing	• Aug 1-Sep 30 • 30-50% of plot left unmown each year	• Aug 15-Feb 15 • 15-85% of plot left unmown each year or whole plot mown every 2 years
Mowing plus grazing	• mowing Aug 1-Sep 30 • 30-50% of plot left unmown each year • grazing May 1-Oct 15, max 0.2 LSU/ha (max. stocking rate 10 LSU/ha), in floodplains onset of grazing 2 weeks after water goes down • grazing by Konik horses allowed all year round at max 0.2 LSU/ha	• mowing Aug 15-Feb 15 • 15-85% of plot left unmown each year or whole plot mown every 2 years • grazing May 15-Jul 31 up to 0.5 LSU/ha; Aug 1-Oct 31 up to 1 LSU/ha
Grazing	• grazing May 1-Oct 15 • max 0.5 LSU/ha before July 20, 0.5-1 LSU/ha afterwards (stocking rate 10 LSU/ha) • in floodplains onset of grazing 2 weeks after water goes down (except for Konik and Hucul horses)	grazing alone not allowed
OTHER REQUIREMENTS		
Biomass removal	biomass to be baled and removed within 2 weeks after mowing	biomass to be removed within 2 weeks after mowing or baled within 2 weeks after mowing and removed by March 1
Fertilisers	up to 60 kg N/ha yearly (not allowed on floodplains)	not allowed
Drainage	not allowed	not allowed

be combined with payments for Less Favoured Areas (LFA; see **Boxes 5.4** and **5.5**). These are available for land in areas with 'natural or other specific constraints' like less productive and fertile soils of mountain areas, or floodplains.

Since 2014, the EU's CAP regulation allows also for the provision of the so-called Natura 2000 payments. These are meant to compensate for the restrictions or additional costs experienced by a farmer due to measures prescribed by a management plan of a Natura 2000 area. As opposed to the entirely voluntary agri-environmental schemes, this tool in theory could pay compensation for measures not chosen by the farmers themselves. Due to the lack of Natura 2000 management plans, this tool has so far never been used as originally intended. Instead, at least in Poland and Lithuania, these payments are simply paid out as a top-up on agri-environmental al schemes when the land concerned is located within a Natura 2000 area. If nothing else, this way of making use of Natura 2000 payments at least increases the probability of take-up of the schemes within Natura 2000 areas.

Germany does not have any agri-environmental scheme targeted specifically at Aquatic Warblers, but support is available for various ways of extensive grassland management, which could be used by conscientious land users to fit with

Box 5.5

Aquatic Warbler packages in the Lithuanian 2014-2020 agri-environmental scheme

ŽYMANTAS MORKVĖNAS

In Lithuania, schemes addressing Aquatic Warbler conservation have been in place since 2015 (**Table 5.3**, **Fig. 5.17**). The two 'Landscape stewardship programme' packages target the conservation of the Aquatic Warbler in meadows and wetlands. The package 'Support to non-productive investments linked to the achievement of agri-environmental and climate objectives' provides resources for a single activity to restore habitat (bush and reed removal, mowing of old grass), awarded according to an individual plan agreed with a municipality officer. In the year following its implementation there is an obligatory switch to a relevant Aquatic Warbler agri-environmental scheme option. An Aquatic Warbler package can be combined with other subsidies: direct payment (c. 143 €/ha), LFA payment (61 €/ha), and Natura 2000 payment (70 €/ha), as of 2015.

► **Fig. 5.17**
Title page of a publication addressing Aquatic Warbler-friendly farming in Lithuania (design: Baltic Environmental Forum).

► **Table 5.3**
Aquatic Warbler packages in the Lithuanian AES 2014-2020.

Name of package	1) Landscape stewardship program: a) Aquatic Warbler conservation in natural and semi-natural meadows b) Aquatic Warbler conservation in wetlands 2) Support to non-productive investments linked to the achievement of agri-environmental and climate objectives
Eligibility	area pre-defined on the basis of expert research and fixed by GIS layer (which can be modified by the competent authority on annual basis)
Payment	1a: 291 €/ha 1b: 160 €/ha 2: payment based on concrete cost calculation for the site, approved by the municipality, but cannot be above to 80,000 Euro per investment
Mowing	1a: July 1-31 if Aquatic Warblers absent, after August 15 in breeding areas; timing of mowing determined by the administration of protected areas 1b: after August 1, mowing intensity 50% of plot each year
Grazing	up to 1 LSU/ha (until October 15)
Biomass removal	until October 1 (exceptionally March 1)
Fertilisers	not allowed
Drainage	not allowed

the requirements of Aquatic Warblers. But they would not be suitable to ensure Aquatic Warbler-friendly land management of farmers without their own interest in Aquatic Warbler conservation.

It is now important to closely monitor the effects of the schemes. Monitoring projects in Poland are already running. In a project run by OTOP the effect of the agri-environmental scheme on birds, as well as spiders and plant communities is being monitored. Another, country-wide monitoring scheme covering birds and plant communities is run by the Polish Institute of Technology and Life Sciences. Based on the knowledge gathered from implementation, monitoring, and research projects, the existing schemes need to be continuously improved.

Pending further scientific monitoring evidence, the results of the four Polish and Lithuanian Aquatic Warbler LIFE projects (see above) have shown, that the schemes in both countries have proven to be highly attractive for land users and very efficient in increasing Aquatic Warbler numbers. This is a very rare finding among agri-environmental schemes across the EU. Most schemes are so general that an effect on the envisaged target is unlikely to be measurable or has such a low uptake rate by farmers that any significant effect is highly unlikely. There are a number of factors that explain the success of the Aquatic Warbler schemes in Poland and Lithuania:

- the schemes are highly targeted with a clear expected outcome (more Aquatic Warblers);
- the eligibility of land for the schemes is very restricted and depends on the confirmed occurrence of the species or the designation of the land as a prospective habitat for the species by specialised experts;
- the prescriptions of the schemes are exactly guided by the management needs of the target species, with the newer schemes making provision for difference in the management requirements at different sites;
- licensed ornithological experts decide on the exact management provisions for each area within the brackets set by the schemes;
- the payments provided by the schemes are very attractive for land users, which leads to an extremely high proportion of eligible land covered by the schemes and therefore to a high proportion of the Aquatic Warbler population benefiting from management under the schemes.

These factors set the Aquatic Warbler schemes apart from schemes for other bird species, like those for the Corncrake. A recent review of their effectiveness (Bellebaum & Koffijberg 2018) has shown that they were only effective in Scotland, where over 50% of all Corncrake occurrences were covered by respective schemes, while the coverage was only 6.2% across the whole of the EU and EFTA countries, with schemes not always suitable for the species. Therefore, no effects on population level could be found. In Poland, the restriction of the existing Corncrake agri-environmental scheme to Natura 2000 areas is a key factor for the low uptake of this scheme.

Still, there are also weaknesses in the Aquatic Warbler schemes:

- the Polish scheme is restricted to Natura 2000 sites. This is currently not a major issue for Aquatic Warblers, because almost 100% of the national subpopulation occurs in Natura 2000 areas. But given the intention to increase the area of occupancy of the species to more than triple the areas where it occurs, it will be unavoidable that Aquatic Warblers will eventually start occurring outside Natura 2000 areas. If the scheme was to stay restricted to Natura 2000, a further expansion of the AOO would be a non-starter;
- in Poland the payment per hectare decreases with increasing size of the area of a single farmer covered by the scheme (except for national parks); this rule is intended to support small-scale farmers, but is counter-productive for the conservation of the target species;

- being a regular agri-environmental scheme, participation in the scheme is entirely voluntary and nobody can be required to apply for the schemes if this was considered necessary from a conservation point of view.

In balance, however, the current schemes in Poland and Lithuania are by far the most effective way of ensuring Aquatic Warbler-friendly recurring management currently available. Without these schemes the recent conservation successes in these two countries would not have been possible.

A continuation of the current or further improved schemes is highly recommended beyond the current CAP planning period until 2020. Any schemes will have to be adjusted in the light of ongoing discussions about the shape and structure of the CAP and its nature conservation components post 2020. Conservation organisations, e.g. BirdLife International, are advocating for the end of direct payments paid out practically unconditionally to land owners, and for the introduction of a separate EU nature conservation fund with a budget of at least 15 billion Euro per year. This new fund would take over the financing of the so-called 'dark green' conservation measures for biodiversity, which would include targeted schemes similar to those for the Aquatic Warbler (BirdLife International 2017b). This would free the Aquatic Warbler scheme from restrictions caused by them being essentially agricultural payments, and could make them available also for land not classified as farmland or for entities not considered as farmers, like protected area administrations, even though the overwhelming share of funds would still be expected to be paid out to farmers that engage in nature-friendly farming practices.

Commercial biomass use

In past centuries, biomass use was the only incentive and financing mechanism for recurring habitat management across almost all Aquatic Warbler breeding sites. Local farmers went to mow the sedges because they needed them as feed or bedding for their livestock. But demand for this use of biomass nose-dived during the 20th century, earlier in some countries than in others. Today's high-productive breeds of cattle need higher-energy food, alternative sources of feed are readily available, and bedding is not being used any more in modern stables. Traditional animal husbandry based on fen mire biomass however is not competitive on the current market.

Having said this, the situation appears different in more eutrophic meadows like those in floodplains or polders, where grasses make up a higher proportion of the hay and productivity is higher. The main Aquatic Warbler site in Lithuania, the Nemunas Delta, also contains the production sites of world renowned Goldengrass horse feeds, harvested from 'natural meadows' and exported to feed horses all over Europe and beyond, clearly an economically viable enterprise and worthwhile use of biomass. As described above, in such situations the challenge is rather to apply restrictions to hay production in order to keep habitats suitable for Aquatic Warblers. But the search for alternative uses of biomass is extremely relevant for those Aquatic Warbler habitats that would otherwise be prone to abandonment. The expectation is that proceeds from alternative commercial uses of biomass would contribute to or even cover the costs of habitat management of Aquatic Warbler sites.

There is a great potential for biomass use from wet and rewetted fens which covers the same range of opportunities as biomass production on mineral soils – feed, bedding, fuel, and fibre (**Table 5.4**). Besides traditional agricultural uses for feed and bedding, biomass can be used as a raw material for industry, to substitute fossil fuels for energy generation, or for medicine.

The productive use of wet and rewetted peatlands is an innovative alternative to conventional drainage-based peatland agri- and silviculture. Recently, such land use has been referred to 'paludiculture' (from Latin 'palus' = swamp; Wichtmann et al. 2016). The key principle is to use the land in a way that the peat body is preserved, natural peatland ecosystem services are maintained or restored, and (ideally) peat

Table 5.4 **Examples of biomass utilisation from wet fens in temperate Europe** (after Wichtmann & Tanneberger 2011)**. Q = demand for quality: ++ = high, + = medium, 0 = low).**

Utilisation		Plant growth	Harvest	Q
Agricultural	Ex situ fodder (hay, silage)	wet meadows, reeds	early summer	++
	In situ fodder (grazing)	wet meadows, reeds	whole year	++
	Litter	*Carex* meadows, reeds	summer/autumn	0
	Compost	wet meadows, reeds	late summer	0
Raw material	Roofing material	reeds	winter	++
	Form-bodies	wet meadows, reeds	autumn/winter	+
	Construction/insulation	*Phragmites* and *Typha*	winter	++/0
	Paper (cellulose)	*Phalaris* and *Phragmites*	winter	+
	Basket-ware	willow shrubs	autumn	++
	Timber/furniture/veneer	alder swamps	frost	++
Energetic	Direct combustion and gasification	alder/willow swamps, reeds	autumn/winter	0
	Fermentation	wet meadows, reeds	early summer	+
	Liquid 'sun fuels'	wet meadows, reeds	whole year	0
Other	Officinal	natural mires/plantations (e.g. *Menyanthes trifoliata, Lycopus europaeus, Acorus calamus*)	early summer	++
	Food	natural mires/plantations (mushrooms, berries)	summer/autumn	++

accumulation is re-established or continues. In fen mires, peat is formed by roots, rhizomes, and mosses, and the above-ground herbaceous biomass can (partially) be harvested without substantially harming peat formation (Wichtmann & Joosten 2007). The objective of paludiculture is to maintain and restore the multiple services provided by wet peatland ecosystems, while at the same time allowing biomass harvest. Paludiculture is thus an agri- (or silvi-) cultural production system: it targets the production of plant- or animal-based commodities (Joosten et al. 2016). Along with land use on rewetted, formerly degraded peatlands, it also comprises harvesting of spontaneous vegetation in near-natural peatlands, including Aquatic Warbler habitats. While the former aims primarily at climate protection, the latter is conservation-driven.

In contrast to the use of biomass as a fuel, the use of biomass as material achieves a higher added value. Some traditional ways of material use of biomass include its utilisation as thatch, for paper production, and for weaving (**Fig. 5.18**, **5.19**). Furthermore, many innovative ways have been developed for using Common Reed and Cattail as building materials, each specific use being determined by the particular properties of the raw material. The quality of the raw biomass depends on the water and nutrient supply of the plants, as well as on the management and the species composition of Reed and Cattail stands (Wiedow & Burgstaler 2016). From a climatic perspective, the use of biomass for construction or handicraft (**Table 5.4**) is to be favoured over its use as a fuel, as the sequestered carbon remains stored over the long term. With respect to using fibre from peatlands, Common Reed for thatch has a long tradition in Europe (Rodewald-Rudescu 1974, Wichtmann et al. 2016) and is well established e.g. in Germany, the

Fig. 5.18 **Weaving loom for the production of mats from Common Reed harvested on Schadefähre Island, a former Aquatic Warbler breeding site in Germany, February 2013** (photo: C. Schröder)**.**

Netherlands, and Poland (**Box 5.7**). In western Europe the demand for high-quality reed cannot be satisfied by inland supply and most reed is imported from southern and eastern Europe, Turkey, and China (Wichmann & Köbbing 2015).

Reliable statements on the profitability of paludiculture require solid underlying data. There are long-term experience and established markets with stable prices regarding some forms of biomass utilisation – e.g. reed for thatching. Other products and markets, however, are still being developed and, consequently, prices reflect willingness to pay rather than a market value. Based on a stochastic simulation, the results of Wichmann (2016) indicate that the economics of reed as a construction material are more favourable compared with its use in direct combustion and, more strongly, compared to its use as biogas.

Table 5.4 shows that the different intended uses of biomass demand very different dates of harvesting and have different requirements regarding the quality of the biomass harvested. Whereas early summer harvesting might be possible or even desired in Aquatic Warbler habitat restoration (see Chapters 4.1 and 4.4), all fen peatlands occupied by the Aquatic Warbler require late summer, autumn or winter harvesting. In addition, breeding sites have a water table close to the soil surface, a large area (usually 200 ha and more), and are usually mainly covered by sedges (Chapter 2.3).

A study conducted within the first Polish Aquatic Warbler LIFE project evaluated possible alternative uses of biomass against the habitat management requirements of typical Aquatic Warbler sites. In the end, three main possible uses were compared: composting, biogas production, and solid fuel production for combustion.

Composting of the biomass harvest is a simple and inexpensive option, but its potential to create income is very low. While it might be possible to sell compost for garden use in and nearby larger urban agglomerations, the demand for such compost is expected to be very low in peripheral areas, where people produce their own compost in gardens and where Aquatic Warbler sites are typically located. Additionally, composting does not create any additional climate benefit because all carbon stored in the biomass is left to decompose and be released into the atmosphere.

Biogas production through fermentation would require a harvesting date in late spring or early summer, when protein, sugar and moisture levels of the biomass are higher than later in the summer or in autumn and winter. But with Aquatic Warblers regularly still breeding in August (see Chapter 2.5), such early harvesting dates would be detrimental to the conservation of the species. Even if protected area regulations were to prescribe a late harvesting date, economic interests would always give rise to a desire to push for ever earlier mowing dates, thus creating an eternal cause of conflict.

The use of the biomass as solid fuel to be used as an alternative to fossil fuels, e.g. coal, however, was found to be most in line with the requirements of the Aquatic Warbler. For this purpose, a harvesting date at the end of the growing period late in summer or even in winter is best, when the biomass has achieved its maximum dry mass, and moisture content is lowest. This coincides with the needs of Aquatic Warblers in occupied good quality habitat. Additionally, the solid fuel from biomass

▼ **Fig. 5.19**
Insulation plaster from reed fibres and loam produced by Mineralische Rohstoffmanagement GmbH, Friedland, Germany, 2013 (photo: N. Körner).

► **Fig. 5.20**
The pelleting facility in Trzcianne is a big and convoluted construction divided into two separate rooms: the dust-intensive drying and shredding of biomass takes place in one room, and the pressing, cooling, and storage take place in the big hall. Biebrza Valley, Poland, February 2013 (photo: L. Lachmann).

contributes to the reduction of greenhouse gases when replacing fossil fuels. For this purpose, biomass could be sold as whole bales or pressed to briquettes or smaller pellets, depending on the local demand. There is an existing demand for this type of fuel, which is expected to grow with increasing 'green' targets for local and regional heating plants and the perspective of a functioning carbon certificate trade in the future. Besides power plants of any size, there is also the potential of selling the produce to private customers for use in special biomass boilers to heat houses. Therefore, the most promising land use option for Aquatic Warbler breeding sites is using plant biomass for energy production.

This approach has since been applied in several Aquatic Warbler conservation projects, as described above. It was the focus of the second Polish Aquatic Warbler LIFE project implemented between 2010 and 2015 by OTOP. Its main goal was to link the production of biomass as a renewable energy source with the large-scale mechanised management of Aquatic Warbler habitat. While existing briquetting or pelleting facilities, and even an oven for the combustion of whole bales of biomass at a nearby cement factory could be used in some of the project areas, a new pelleting line was assembled from scratch in the village of Trzcianne in the Biebrza Valley (**Box 5.6**, **Fig. 5.20**).

Box 5.6
The pelleting facility in Trzcianne, Poland
ŁUKASZ MUCHA & JUSTYNA KUBACKA

In the second Polish Aquatic Warbler LIFE project, 'Aquatic Warbler and Biomass' (2010-2015), OTOP bought a former sawmill at the edge of the village Trzcianne, dubbed the 'Aquatic Warbler land' by its mayor, and fitted a biomass pelleting line into the building. The yearly production capacity of this plant at the edge of the Biebrza Valley in Northeast-Poland is about 2,000 t of pellet. The declared goal of the facility is to support the Aquatic Warbler friendly management of fen mire habitats in the Biebrza Valley. The biomass used for the production of the pellets is a mixture of reeds, sedges, Reed Canary Grass (*Glyceria maxima*) and other grasses.

Up to 400-500 t of biomass are harvested in OTOP's own nature reserves in the buffer zone of the Biebrza National Park. The majority of the biomass is obtained free of charge from the farmers that lease Aquatic Warbler habitat from the Park and implement the habitat management using agri-environmental and direct payments. They have an obligation to remove all mown biomass from the land. OTOP therefore only has to cover the costs of transport from the edge of the fields to the biomass plant. Approximately 25% of the raw material is additionally purchased from farmers in the vicinity who mow land without connection to Aquatic Warblers, in order to be able to use the whole capacity of the plant. The price per tonne of raw material with a moisture content of 20% was up to 125 PLN (c. 30 Euro) in 2016.

The biomass productivity in prime Aquatic Warbler fen mire habitat is a maximum of 2 t/ha of hay with a moisture content of up to 20%. Yields from homogeneous reed stands, however, can reach 10 t/ha and more. Biomass is collected in the form of bales, with tractors and trailers, from areas within up to 60 km from the plant if free of charge or up to 40 km from the plant if paid for. Biomass could be obtained from a wider area if the plant had lorries to load more bales per journey. ►

Box 5.6 contd The pellet produced in the plant has a caloric value of 15.8 MJ/kg, comparable to the value of coal or wood. It is marketed under the brand name 'OTOPellet', and as such has already gained recognition among the local population. 95% of the produced pellet is sold to heat and power plants (cogeneration plants), and the remaining amount is sold to private buyers. The economic balance of the Trzcianne biomass plant is positive, i.e. it earns more than it spends. It also has a positive socio-economic impact, creating four local jobs. However, the net income is insufficient to contribute significantly to financing active conservation measures in the Aquatic Warbler habitats in the OTOP reserves. This was especially true in the years 2014-2016, which saw very poor winters, little snow cover and dry summers, which translated into low production of biomass and an increase in the price of raw material and a reduction of its availability. Another role is probably played by the recent tendency to reduce the mowing frequency on fen mire habitat that has been brought up to optimal habitat quality, as research funded by OTOP within two LIFE projects showed that breeding productivity of Aquatic Warblers in the Biebrza fens is best around two years after mowing has taken place (Kubacka et al. 2014, see also Chapter 2.3 and 2.5).

In any case, the biomass plant solves the problem of the enormous amounts of unused biomass arising from thousands of hectares mown for the Aquatic Warbler in the Biebrza Valley and provides a solution to the requirement of removing it from the fields and their surroundings in order to avoid the release of nutrients into the site and support the mesotrophic character of the habitat. And the economic viability can vary with the development of selling prices of the final produce. Increasing the share of private customers would mean an increase in the profit of the plant.

In Lithuania, in the Žuvintas Biosphere Reserve a biomass pellet production line was set up within the LIFE project 'Baltic Aquatic Warbler' in 2013 (**Fig 5.14**). The pellet production enables the farmers to make up for the losses created by the requirement to delay mowing dates until late summer, which makes it impossible to use the biomass as fodder. Following the establishment of the pelleting line, the administrative building of the Žuvintas Biosphere Reserve started to be heated by pellet. Another biomass plant is foreseen to be built in the Nemunas Delta area as part of the recently commenced second Lithuanian Aquatic Warbler LIFE project.

A biomass briquetting facility was also purchased for the Sporava Nature Reserve in Belarus as part of the ICI project on the restoration and management of peatlands in Belarus (2008-2012) and another one is planned to be established at the Zvaniec Nature Reserve as part of the 'ClimaEast' pilot project (2014-2017).

In contrast to the novel use of biomass for energy, the material use of reeds from the most important remaining Aquatic Warbler site of the Pomeranian subpopulation predates the conservation efforts for the Aquatic Warbler and clearly creates a superior economic value, as presented in **Box 5.7**. The necessary alignment of commercial production and the needs of Aquatic Warbler conservation are currently provided by a close cooperation between conservation authorities, NGOs, and the land users.

The key question is, to what extent alternative uses of biomass from Aquatic Warbler habitats can contribute towards the costs of habitat management. The answer to this question depends on the local conditions. In typical cases, the use of biomass for energy production as alternative fuel appears to be the most appropriate option. In this case the economic viability will be determined among others by the following factors:

- the capacity of the production line;
- the availability and price of raw material, determined by productivity of the habitat and mowing frequency;
- the distance between the fields and the biomass plant;
- the machinery available for the transport of the biomass;
- the local demand for the final product and the prices that can be obtained.

The example of the pelleting facility in Trzcianne (**Box 5.6**) shows that in this case the profit obtained currently only contributes a small part to the costs of the management of Aquatic Warbler habitats. A closer look into the economics of other biomass facilities established in conjunction with Aquatic Warbler conservation efforts would surely be very interesting. At any rate, the demand for biomass fuel makes it possible to utilise cut biomass, if only without any profit, thus eliminating a potential hindrance in land management posed to farmers due to the difficulty to dispose of biomass arising from habitat management. This is important because land managers who receive direct or agri-environmental payments are obliged to remove cut biomass from the site.

The construction of a biomass facility for briquetting or pelleting is very costly, and the profit margin – at least when biomass is sourced from prime Aquatic Warbler habitat – is small. This explains why most of the facilities mentioned in this chapter have been established using project funds. However, across Poland a number of similar facilities exist that have been set up following purely entrepreneurial interest. In the Lublin region in Southeast-Poland, such facilities have been used to sell biomass from Aquatic Warbler sites, too. It therefore can be expected that in areas with higher biomass productivity per hectare the profitability of such plants can be acceptable.

To circumvent the high costs of setting up a separate biomass plant, an alternative solution to explore in the future could be the combustion of whole bales. This is possible where local heat and power plants exist that are equipped for the burning of whole bales. An example from a former Aquatic Warbler breeding site in Northeast-Germany is presented in **Box 5.8**.

A potential risk posed by using biomass for commercial purposes is that Aquatic Warbler habitats could be overexploited, especially when agri-environmental schemes or other conservation schemes were to be discontinued and demand for biomass could grow. This is where restrictions imposed by protected areas or Natura 2000 management plans come into play. These conservation plans need to contain the relevant prescriptions necessary to deal with such a potential situation.

Box 5.7
Using Common Reed as a building material at the Rozwarowo Marshes

FRANZISKA TANNEBERGER, COSIMA TEGETMEYER & MAREK DYLAWERSKI

The Rozwarowo Marshes in Northwest-Poland have been used for harvesting reed for thatch for 25 years. Because of its size and its international importance for biodiversity conservation it is a particularly interesting example for regional value creation and potential synergies between agriculture and nature conservation. The Rozwarowo Marshes (c. 1,800 ha) are situated between the towns of Kamień Pomorski and Wolin. The mire has never been strongly drained, but is covered by a network of ditches, and water levels are being artificially regulated. Nutrient conditions are mesotrophic to slightly eutrophic. The entire peatland area is designated as Important Bird Area (IBA), mainly because of the breeding subpopulation of the globally threatened Aquatic Warbler.

The land use history has been changeable, particularly because of the border situation between Prussian and Swedish influence. Before 1945 the peatland was used as meadow and pasture and became abandoned afterwards. In winter 1988/89 Alfred Smolczyński harvested 25,000 bundles of reed for the first time. Today, the Smolczyński family owns and manages the site together with two other families and reed is harvested on c. 75% of the area (c. 1,200 ha). The Smolczyński company produces thatched roofs (www.trzcina.com.pl) and has 50 employees in Poland and 20 employees in Denmark. The foundation of their entrepreneurial success is the integration of the entire value adding chain from harvest (**Fig. 5.21**) to roof thatching into one company. They offer their service all over Europe, with a focus on Poland and Denmark. Next to classic thatched roofs, they offer also various thatched garden pavilions.

In Poland, there are eight companies harvesting reed on 2,000 ha. Some 50% of the harvest is sold to Denmark, 20% stays in Poland, 10% is sold to Germany, and the remainder to France, the Netherlands, and Sweden (A. Smolczyński pers. comm.). For harvesting reed special machinery based on a lightweight tractor model called 'Saiga' with balloon tyres is used. In the future it is planned to use the excess material from cleaning the reed bundles for energy production. It will be collected separately and compacted. In this respect, and also with respect to the water regime, it is an ongoing challenge to balance the interests of nature conservation and reed harvesting. Key considerations that help Aquatic Warblers to live alongside commercial reed production are to leave a part of the litter on site to enable nest building, to keep water levels during breeding season below 10 cm above soil surface, and to minimise nutrient input into the peatland (see Chapter 4.2). The long-term close cooperation between conservationists and land users and effective agri-environmental schemes will hopefully warrant this also in future.

► **Fig. 5.21**
Alfred Smolczyński showing thatch harvested from the Rozwarowo Marshes to Cosima Tegetmeyer, July 2005 (photo: F. Tanneberger).

Box 5.8

The district heating plant at Malchin, Peene Valley, Germany

TOBIAS DAHMS & ANKE NORDT

A pioneering concept for the utilisation of biomass from rewetted peatlands at Malchin is the close cooperation between the agricultural enterprise Voigt and the local energy supplier Agrotherm GmbH, who opened a heating plant to supply a district heating network for the town of Malchin, in the German federal state of Mecklenburg-West Pomerania. As a result of a major fen restoration project ('Peenetal/Peene-Haff-Moor') in a former Aquatic Warbler breeding area, the fodder quality of the pastures used by farmer Voigt declined, which frustrated the continuation of grazing with suckler cows. In order to continue farming on the rewetted sites, a concept for the thermal utilisation of the biomass was developed since 2006. An ideal opportunity was the short distance to the town of Malchin, which is situated 12 km from the farm and has a district heating network that solely operates with natural gas. It was possible to utilise regional biomass from sedges, rushes and Reed Canary Grass by integrating a biomass boiler into the district heating network. The biomass of some 300 ha annually is now used to produce 800-1,000 t of biomass fuel, which equals to 2,900-3,800 MWh or 290,000-380,000 l of heating oil. The plant currently provides district heating to 490 standard flats, two schools, and a day-care facility for children.

The biomass boiler is made by the Danish company LIN-KA/Danstoker and has a thermal capacity of 800 kW. The required biomass is harvested by Voigt agricultural business during dry periods in summer using adapted machinery, is then pressed into round bales and transported to the boiler site. There, the bales are fed continuously into the boiler of the district heating plant with a conveyor belt, which can hold 24 bales of biomass. The investment costs for a biomass boiler, par- ►

Carbon credits

Aquatic Warbler habitat restoration and management could also be funded through the so-called 'carbon projects', which primarily aim at reducing greenhouse gas emissions. Aquatic Warblers breed in peatlands, which are the most space-effective carbon stocks of all terrestrial ecosystems. While covering only 3% of the world's land area, peatlands contain 500 Gt (gigatonnes) of carbon, which is equal to the carbon stock of all terrestrial biomass, and twice that of the total forest biomass of the world. When drained, peatlands become vigorous sources of greenhouse gases (GHG, carbon dioxide CO_2, and nitrous oxide N_2O). Globally, degraded peatlands emit 2 Gt CO_2 per year, which means that 0.3% of the land surface is responsible for almost 5% of the total global anthropogenic CO_2 emissions (Joosten 2009). The relationship between peatlands and climate became painfully apparent in 1997/1998, when peat swamp fires in Southeast-Asia released 3-9.4 Gt of CO_2 (Page et al. 2002) and thus nullified 18-57 times (!) the annual global GHG reduction target of the Kyoto Protocol.

The UNFCCC requires national GHG accounting and offers emission trading instruments of the UNFCCC Kyoto Protocol ('compliance market'), e.g. Green Investment Schemes (GIS), Joint Implementation (JI), and the Clean Development Mechanism (CDM). However, these instruments were, and still are, for various reasons not functioning with respect to peatlands. Therefore, in 2008 activities started to bring carbon credits from peatlands to the 'voluntary market'. Here, emission reductions are purchased for the good name they infer (corporate social responsibility) and for promotional, or marketing, opportunities. The voluntary market requires excellent quality standards for carbon reduction projects (what will be done, how much will be reduced, how it will be done…) since a reputation is easily tarnished.

MoorFutures (www.moorfutures.de) was established in Germany in 2011 and delivered the first carbon credits issued for peatland rewetting worldwide (Joosten et al. 2015). Based on the regional Moor-

Box 5.8 contd ticularly for herbaceous biomass, are significantly higher than for boilers operated on fossil fuels. The net investment for the combustion plant (including fuel processing, flue gas filters, buffer store, and installation) amounts to 630 Euro per kW of nominal heat output. Additionally, funding is needed for the building shell, chimney, storage, and machinery. However, the great advantage compared to fossil fuel boilers is the much lower fuel cost. Agrotherm GmbH calculates fuel costs of 3.9 Euro per GJ of heat provided (L. Bork pers. comm.). Altogether, there is the advantage of reduced net heat production costs and long-term price stability. The energy concept of Malchin shows how local networks may contribute to the implementation of pilot projects and is an inspiring example for many other regions.

Future standard, the first rewetting site (polder Kieve in Northeast-Germany) generated c. 13,000 credits (i.e. tonnes of emission reduction). Of these, to date, c. 12,000 credits have been sold at a price of 35 Euro per tonne. Other German federal states have replicated this approach and in total three peatlands have now been rewetted funded by MoorFuture credits, with two more coming in 2018. All of them are too small to serve as a potential Aquatic Warbler breeding site, for which a minimum size of 200 ha is assumed. As the commercialisation of climate services comes with the danger of a partial, single-dimensional view of peatlands, neglecting or even damaging other ecosystem services, since 2015 MoorFutures has provided a methodology to assess such services in a simple, conservative way (Joosten et al. 2015).

Major efforts to introduce peatland rewetting into the world's benchmark standard for voluntary emission reductions, the Verified Carbon Standard (VCS – called 'verra' since February 2018, www.verra.org) have been made in the framework of the project 'Restoring Peatlands and Applying Concepts for Sustainable Management in Belarus' (2008-2011), funded by the ICI and presented in Tanneberger & Wichtmann (2011). The project has helped to make 'Wetland Rewetting and Conservation' eligible as a VCS category related to agriculture, forestry and other land use (AFOLU) in 2010 (O' Sullivan & Emmer 2011). During the project, a methodology for rewetting of temperate peatlands was elaborated. Full validation and publication at the VCS website only took place in summer 2017. Currently, a project document for two Belarusian peatlands is finalised for joint submission under VCS and Climate, Community and Biodiversity Association (CCB) standards in 2018.

Both the Kyoto compliance market and the voluntary market require that the claimed emission reductions are 'real, measurable, verifiable, and additional'. An obvious approach would be to measure on site all GHG fluxes that occur before, during, and after the project intervention. Unfortunately, the laborious and complex techniques required for this make comprehensive direct flux measurements prohibitively expensive (Joosten & Couwenberg 2009). Therefore, it is recommended to assess emission and its reduction from peatland rewetting projects using vegetation as a proxy following the so-called GEST approach (Couwenberg et al. 2011). This method follows the criteria of the VCS. Another important issue is that emission reductions must be assessed against a baseline. In contrast to static, 'historical' baselines e.g. of the Kyoto Protocol, VCS uses a forward-looking baseline, i.e. the difference in emissions between a situation with project implementation (project scenario) and a situation without such a project (baseline scenario) is assessed for the project period.

In general, Aquatic Warbler-related carbon projects can take two approaches:

1. habitat restoration: a project focused on rewetting of drained peatlands (e.g. under a VCS Wetland Restoration and Conservation project category), supplemented by a biofuel energy project (e.g. under VCS plus CCB) to cover the costs of vegetation management;
2. habitat maintenance: a biofuel energy project to cover the costs of vegetation management (see 1).

It is crucial to be clear about priorities (e.g. biodiversity or maximum emission reduction) from the very beginning, as activities targeted at maximum emission reduction do not always coincide with those targeting maximum biodiversity benefits.

Any carbon project inside or outside a national greenhouse gas accounting system will have its specific cycle, for example:

- design (using an existing methodology, describing activities and expected emission reductions);
- validation and registration through a certified body (e.g. under VCS);
- baseline setting and monitoring (using standardised procedures, e.g. GEST mapping);
- verification and certification through the certified body;
- issuance of carbon credits for sale.

All in all, funding sourced through the sale of carbon credits is an interesting and promising instrument to fund the restoration of peatlands and possibly also the recurring management of peatlands for Aquatic Warblers. But the implementation of this tool is still very much in its infancy and is as yet far from being a proven and tested mechanism. Much of its future viability will depend on the development of the world market price for CO_2, which in turn depends on the establishment of an efficient trading system for carbon credits.

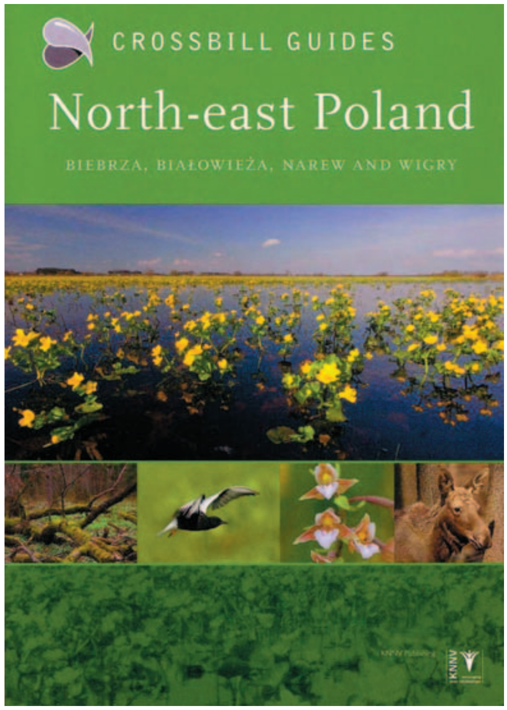
Ecotourism

In this chapter, ecotourism is understood as nature-based tourism, i.e. a form of tourism in which non-local visitors find leisure in going to an area to enjoy its nature, regardless whether this nature is the goal (naturalists, birdwatchers, etc.) or an enjoyable scenery (hikers, ramblers, etc.). This ecotourism is often seen as an important means to support nature conservation. Either it does so directly, by generating income through entrance fees, or indirectly, by creating jobs in the tourism sector and hence being an incentive to protect areas of valuable nature. Since many valuable natural areas are situated in economically weaker regions, and unsustainable exploitation of these natural resources is the main perspective on economic well-being, the ecotourism alternative is often embraced as a means to preserve natural areas. Moreover, nature conservationists often use ecotourism as an argument in the debate with other stakeholders, because they feel that economic arguments will be perceived as more legitimate than more 'diffuse' arguments like intrinsic value and aesthetic appreciation. This chapter explores ecotourism as a means to finance habitat management for the Aquatic Warbler and as a tool to generate income.

In 2008, the Crossbill Guides Foundation and van Hall Larenstein of the Netherlands conducted a research project (van Drunen & van Verstegen 2008, **Fig. 5.22**) which traced the financial flow between ecotourism and local stakeholders and the Biebrza National Park in Poland. The conclusion was twofold: firstly, ecotourism's direct financial contribution to the management of Aquatic Warbler habitat is very modest, and secondly, the actual and potential role of ecotourism as an engine for the local economy and thereby an indirect support for nature conservation is considerable.

An estimated 50,000-60,000 ecotourists annually visit the Biebrza Valley. In 2014, according to the Biebrza National Park webpage, about 32,000 entry fees, and kayaking, rafting, or angling permits were purchased. The net income from these sources totalled 360,000 PLN (c. 82,000 Euro), which was 4.4% of the overall net income of the Park (Biebrza National Park 2014). The fees and permits hence do not generate a major source of income, although in absolute terms they do make a meaningful contribution to the Park's budget. It should be noted that the real number of visitors to the Park will be up to three times higher, as not all of them purchase entry fees (Ramotowska 2006).

Since the Aquatic Warbler became one of the target bird species in the Polish agri-environmental scheme, the Biebrza National Park has been letting its, meadows and pastures to farmers, who have been benefiting from attractive subsidies (see e.g. **Box 5.4**). Today, most habitats of the Aquatic Warbler are managed by lease-holders in line with the requirements written in the scheme and supplemented by the Park. The Park therefore does not incur significant costs of habitat management for the species. If it did, for example when subsidies



◄ **Fig. 5.22**
The Crossbill Guides Foundation in the Netherlands, led by Dirk Hilbers publishes nature travel guides like this one for Northeast -Poland, but also supports research into the relationship between ecotourism and nature conservation and provides small grants for nature conservation from the profits of their books (picture: Crossbill Guides Foundation).

are discontinued, the estimated costs would be as follows: the price of mowing a hectare of marshland with an adapted piste-basher is about 600-650 PLN (c. 150-160 Euro), including biomass collection, labour, and equipment maintenance (Ł. Mucha pers. comm.). The area of Aquatic Warbler habitat in the Park is 17,432 ha (Marczakiewicz & Grzywaczewski 2008). The frequency of mowing is variable, depending on the speed of plant succession. There is wet fen that can only be mown with a piste-basher and slightly drier sites that can be mown with a twin-wheel tractor. Making a simplified assumption that entire suitable habitat is mown with a piste-basher every four years, the annual cost of habitat maintenance would then total 2,832,700 PLN (c. 700,000 Euro). The entry fees and permits contribute about 13% to this amount. Overall, this type of income would only modestly contribute towards the management of the Aquatic Warbler habitat, especially that there are several other expenses in the Biebrza National Park, such as protection of other habitats and species, or costs of maintenance and administration.

Ecotourists visiting the Biebrza region also spend money on accommodation (hotels and guesthouses, **Fig. 5.23**), restaurants, transportation (fuel and bike, or kayak rental), guided nature tours (**Fig. 5.24-26**), or pur-chase of products (groceries, souvenirs, etc.). In the form of taxes, a fraction of this money flows to the state budget and local administrations. From the state budget it then returns to the Park as part of the yearly governmental subsidy. In 2014, the income tax received by the Polish state budget from accommodation providers offering at least ten beds, located in the two main counties covering the Biebrza National Park, the Mońki and Grajewo districts, amounted to about 380,000 PLN (c. 95,000 Euro; Statistical Office in Biał ystok 2015). This was nearly 9% of the 2014 governmental subsidy granted to the Park (Biebrza National Park 2014). Income from other tourist services will likely double this amount. Hence, nature is a valuable economic resource to the region and through the services offered, ecotourism can be an important indirect support for the Biebrza National Park. Unfortunately, the Biebrza Marshes, unlike local administrations, cannot rely on ecotourism, as the subsidy to the Park is independent of the amount of income that is generated for the central and local budgets.

Given that ecotourism has a value, it would be interesting to estimate how much of the tourism potential of the region is contributed by the Aquatic Warbler. Although this has not been properly investigated, there are good arguments to assume that it is quite a lot. Set aside its modest size and drab plumage, to birdwatchers and naturalists, which are the key group of foreign and about one fifth of the Polish visitors to the Biebrza Valley (Kiryluk & Borkowska-Niszczota 2009), the Aquatic Warbler is one of the main attractions. It is rare and has a highly local occurrence. Add to this the fact that the few other large subpopulations in the world are, with the exception of one, in areas that are very difficult to access, and it is clear that the Aquatic Warbler is a very big draw for bird-minded tourists. The Aquatic Warbler could be seen as an emblem of the marshes.

The situation at other Aquatic Warbler sites is similar. The development of nature-based tourism around the flagship species of Aquatic Warbler is being targeted at several other sites. In Belarus for example, 14 touristic routes have been developed in the nature reserves of Middle Pripyat and Sporava, including a route of 10 km along the river Jasieĺda through the middle of the Sporava Reserve (Tanovitskaya 2011).

Thus, whether or not ecotourism contributes directly or indirectly to the financing of necessary habitat management measures, nature conservation in a particular Aquatic Warbler site benefits very much from the perception of exceptionality and uniqueness of the area thanks to the occurrence of the Aquatic Warbler. With this in mind, it is advisable to ensure that visiting tourists will be able to experience a meeting with this special bird. Every tourist who has made this experience will be a new advocate for nature conservation at the site he visited.

▲ **Fig. 5.23**

Signboard advertising the 'Paradise Pond' B&B and beaver observatory just outside the Biebrza National Park, Zajki, Poland, May 2008 (photo: L. Lachmann)**.**

▼ **Fig. 5.24**

Foreign birdwatching tourists enjoying the observation platform at the end of the Ławki Mire boardwalk into the Aquatic Warbler breeding site in the Biebrza National Park – the world's most accessible observation spot for the species. May 2007 (photo: L. Lachmann)**.**

▲ **Fig. 5.25**
The Moose is one of the highlights in Aquatic Warbler habitats and an attraction sought by nature-lovers and photographers (photo: Ž. Morkvėnas)**.**

◄ **Fig. 5.26**
The diversity of mosses and flowering plants in Aquatic Warbler habitats attracts also plant enthusiasts (photo: Ž. Morkvėnas)**.**

6 Recommended research and monitoring in breeding sites

6 Recommended research and monitoring in breeding sites

JOCHEN BELLEBAUM, JANUSZ KLOSKOWSKI & MARTIN FLADE

Successful conservation of Aquatic Warblers relies on the availability of relevant knowledge derived from targeted and effective research and monitoring. Research is done at selected sites in projects of limited duration, specifically designed to gather information of general importance, be it fundamental facts on breeding biology and distribution, or establishing the success of management measures. Monitoring is intended to track the status of populations or their response to management activities using standardised methods over longer periods, at all or at a subset of sites, often using more simplified and cost-effective methods than in research projects. Effects of management should be monitored in each specific case in order to continuously improve it. Monitoring is therefore important wherever breeding sites are subject to regular, and often laborious or expensive management. This chapter presents the current gaps in knowledge and the needs for specific research. It also makes recommendations for monitoring at different levels that are relevant to the effective conservation of Aquatic Warblers in their breeding range.

Current research and knowledge gaps

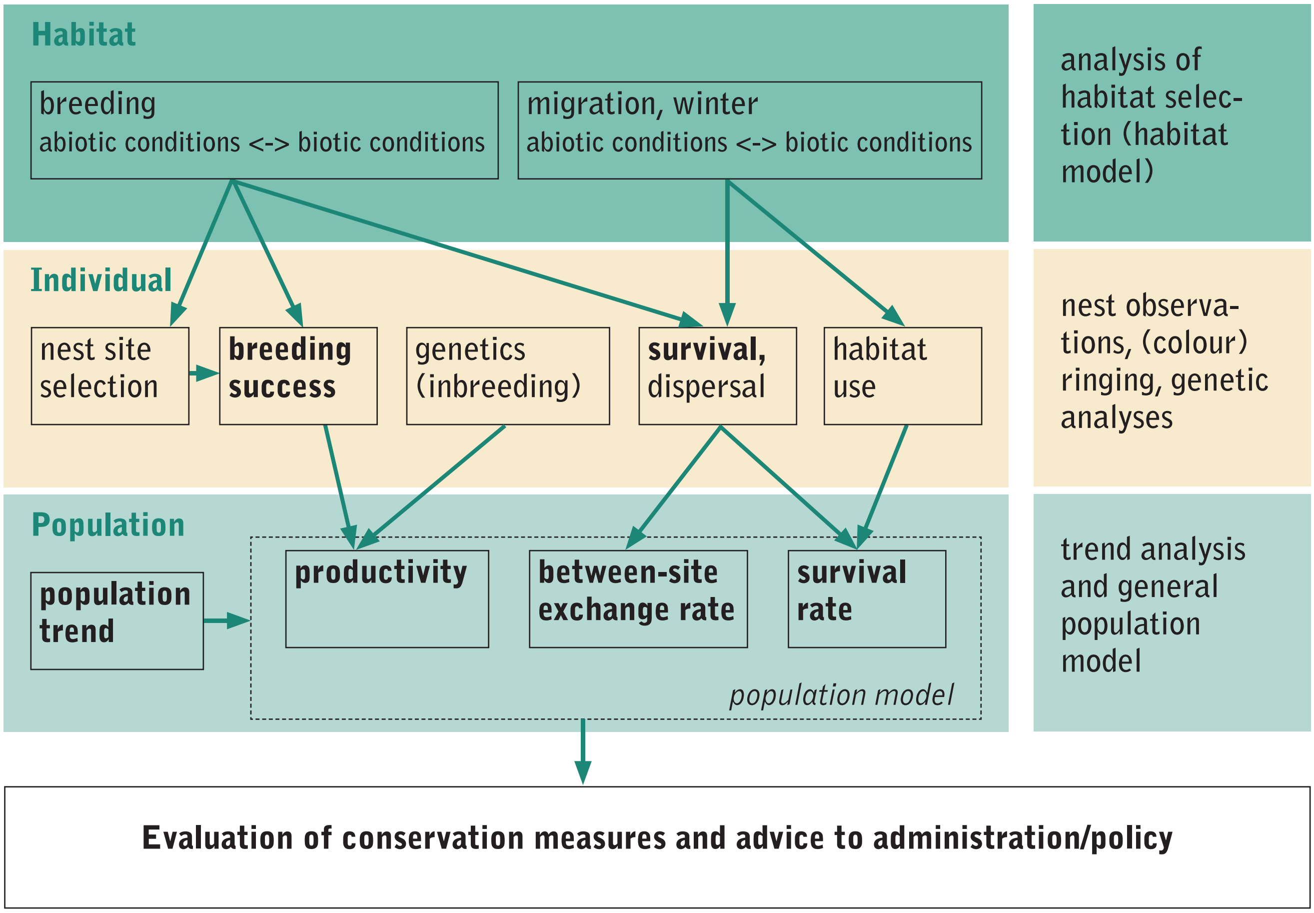
Today, detailed information exists on the species' distribution and habitat requirements at breeding sites. Several studies, some of them including radio-tracking, have gathered data on habitat use by Aquatic Warblers at West-European migratory stopover sites and during winter (Jubete et al. 2006, Arbeiter 2009, Le Nevé & Bargain 2009, Kerbiriou et al. 2011, Flade et al. 2011; see also Chapters 2.9 and 2.10), and we may expect that the knowledge about habitat requirements during winter will expand.

A lot of effort has been recently put into the evaluation of the effects of habitat management measures, especially within the various LIFE projects on Aquatic Warbler conservation. These efforts need to be continued to obtain robust evidence supporting or correcting guidelines for management activities.

By contrast, knowledge about the ongoing population processes is still weak. Successful conservation, especially of small remnant subpopulations, for instance the Pomeranian subpopulation, has to take into account key population parameters, such as productivity, survival, and natal or breeding dispersal. These processes are essential for understanding the dynamics of local breeding populations, and properly assessing their future perspectives (**Fig. 6.1**). Restoring former and creating new breeding sites has a lower chance of success if these processes remain poorly defined or are ignored. The Pomeranian subpopulation in particular will need an improved restoration strategy based on a better understanding of population dynamics. Most of the information needed to conserve Aquatic Warbler subpopulations has to be derived from studies at the level of individuals and subpopulations. This concerns estimation of productivity and survival, population demography, as well as other types of response to management activities. Taken together, the results of such studies form the basis on which we can predict the future fate of subpopulations (**Fig. 6.1**). Also, more information is needed on factors shaping individual life histories, such as costs of reproduction (including double brooding) and trade-offs inherent in promiscuity, the mating system prevalent in the species.

Breeding productivity

Breeding productivity is the ultimate measure of success for the conservation of breeding habitats, derived from the average number of fledglings per nest and the number of nesting attempts. Breeding productivity has been studied in three of the most important breeding sites in Belarus



▲ **Fig. 6.1** **Information relevant to understand population dynamics to support conservation at different levels** (adapted from Baillie 2001). **Bold print indicates a high priority for research and monitoring.**

(Dzikoje, Zvaniec, and Sporava; Vergeichik & Kozulin 2006a) and in two key sites in Poland (Biebrza Valley and Chełm Marshes; Kubacka et al. 2014, Kubacka et al. in prep.; see also Chapter 2.5). No information is available for other major breeding sites and therefore continuation of breeding productivity studies is desired.

Understanding breeding productivity can also be supported by the juvenile to adult ratio on migration (see also Chapter 2.9). Studies have reported a decrease in the proportions of juveniles ringed on autumn migration after 2000 in Portugal and Spain (Jubete et al. 2006, Neto et al. 2010, A. Le Nevé pers. comm.). However, this decrease is not clear and could be caused by a decline in breeding productivity only in one subpopulation, and is not confirmed by ringing data from France, which are based on much higher sample sizes (A. Le Nevé pers. comm.). There is also no evidence for a low or declining breeding success at the studied sites (see Chapter 2.5). It will be important to further study the juvenile to adult ratio during autumn migration, especially across a broad range of latitudes, and making sure that data is based on standardised mist-netting methods.

Breeding productivity should be recorded also in order to establish the effect of habitat management, beyond the standard monitoring of the number and distribution of singing males, especially in areas subject to dedicated habitat management measures. Proper funding for at least three years should be made available for such studies. An index based on counts of females feeding broods is recommended for very basic studies, which only seek an approximate estimate of nest densities, but without recording the location of nests and the number of chicks just prior to fledging (which correlates with the number of fledged young) it will only act as a proxy of productivity. Also, lack of knowledge on how many nests failed will make it impossible to estimate the success rate (i.e.

whether any young fledged or not), which is a determinant of productivity. If more precise and reliable estimates are required, search and monitoring of nests appears to be superior to search of feeding females, especially that both will be comparably laborious.

Where individual breeding success is found to be low and possibly limiting population growth, further studies are necessary to identify the causes. Some important possible causes to consider will usually be nest loss due to flooding, predation, or land use, shortage of nestling food, and inbreeding (see below). Previous studies have identified a range of potential predators on Aquatic Warbler nests (Dyrcz & Zdunek 1993b, Vergeichik & Kozulin 2006), however, the predators responsible for the largest proportion of nest losses remain unknown. Research on nest predation requires high nest search efforts, because some nests can be predated prior to detection by observers, and should be supported by unobtrusive monitoring with mini video cameras. Studying food supply to nestlings can be done using video cameras or observation, which, however, may involve disturbance due to repeated visits to the nest. Invasive methods, such as neck-collar sampling on nestlings are not advised, and studies should use faecal sampling wherever possible to minimise potential harm to nestlings (Tanneberger et al. 2017). Food data collected should provide information on (i) the amount of food (or even better: energy) delivered to each nestling, the delivery rate, and whether this is sufficient to raise young to fledging, (ii) the size and characteristics of foraging areas, and (iii) seasonal changes in these parameters (see Chapter 2.4). It should be noted that neither sampling of insect abundance, e.g. with sweep nets or any type of traps, nor studies at nests of species other than Aquatic Warblers (even of the closely related Sedge Warbler *Acrocephalus schoenobaenus*) are sufficient to yield reliable quantitative data on the nestling food of Aquatic Warblers.

It must be stressed that any study involving work at Aquatic Warbler nests should be done only by experienced and careful researchers, and only to the extent required by the research question. To limit the risk for the nestlings, due to e.g. increased predation, lower food delivery, or low temperatures, time spent at the nest, frequency of visits and the area of vegetation pressed around the nest should be minimised and nest visits during extreme weather conditions (heavy rain or very low temperatures) should be avoided.

A related question concerns to what extent locations and densities of singing males indicate the presence of nests and densities of breeding females (Dyrcz & Zdunek 1993a). In the Biebrza Valley the density of singing males was shown to be correlated with the nest density and also the number of fledged young per area unit (Kubacka et al. 2014). This issue is important for properly directing management activities at a fine scale, which should aim at optimising conditions for breeding females rather than for the more easily observed and counted singing males. The representativeness of singing male distribution of the location of nests is particularly important in eutrophic sites, where management has to be undertaken during the breeding season and may cause brood losses.

Survival

Together with data on breeding productivity, predicting the future development of Aquatic Warbler subpopulations and assessing the importance of various contributing factors requires knowledge on survival. This is yet insufficiently known, but it is particularly important to clarify the possible role of wintering and stopover sites for trends in numbers. The currently available information on this subject, although limited (see Chapters 2.9 and 2.10), suggests that female survival and emigration rates from poor or deteriorating habitats need to be quantified. Well-designed colour ringing studies to estimate first-year and adult survival and emigration rates or, vice versa, site fidelity in different habitats may thus be an important contribution to future conservation strategies. To be successful, such studies will need proper planning and sufficient resources for continuous field-work and data analysis over a number of years and study sites.

Adult sex ratio

In the Aquatic Warbler, studying adult sex ratio (i.e. the ratio between the numbers of adult males and females in a population) sheds light on sex-dependent survival and improves estimates of population size, which rely on the number of singing males (see Chapter 2.2). It is therefore important to predict breeding productivity, which in the Aquatic Warbler depends on the number of breeding females, due to its uniparental care (see Chapter 2.5). A male-biased adult sex ratio has been found in various threatened bird species, in contrast with non-threatened ones, and could be driven by higher female mortality, because offspring sex ratio does not typically differ from equality (Donald 2007). Adult sex ratio, however, in the Aquatic Warbler has not been resolved convincingly.

Studies involving genetic sexing of Aquatic Warblers captured at the Atlantic coast during migration found an apparent male-bias (Wojczulanis-Jakubas et al. 2013, 2017). However, this bias could be at least partly due to the use of playback (of Aquatic Warbler song) to attract the birds to mist-nets and it cannot be ruled out that alternative migration routes or strategies are used by females, which migrate later than males (Wojczulanis-Jakubas et al. 2013, 2017; see also Chapter 2.9). Still, molecular sexing of birds caught during autumn migration, when adults can be separated from the young of the year, could give reliable estimates of the adult sex ratio in the world population and is highly recommended, provided that playback effects can be ruled out and representative samples are studied. This is not easy and will only be met if data are obtained over large areas and entire migration seasons (Wojczulanis-Jakubas et al. 2017).

Data from breeding grounds, for example the Biebrza Valley, suggest but do not provide clear evidence for a male bias. At breeding sites, males are much easier to observe than females (see Chapter 2.7). Standardised mist-netting and nest search could provide the most reliable estimates of sex ratio but require substantial effort to estimate sex-specific detection or capture probabilities.

Inbreeding depression

Inbreeding depression is a decrease in fitness due to mating with related individuals. In wild populations of birds, it is manifested, for example, in lower egg hatch rates and offspring survival. Inbreeding depression also rapidly erodes genetic variation of a population and therefore limits its adaptive potential. Thus, it substantially affects population viability and extinction risk (Keller & Waller 2002, Frankham 2005, O'Grady et al. 2006). Understanding inbreeding depression is vital for population management, as well as for genetic rescue or translocation projects (Grueber et al. 2008). Inbreeding depression in the Aquatic Warbler is now being studied in Poland (Biebrza Marshes) with the use of a next-generation sequencing (NGS) method (see Chapter 2.8). This method allows for using dense genetic markers and, unlike microsatellite markers, offers a high statistical power to detect and adequately evaluate inbreeding depression. Inbreeding depression in the Aquatic Warbler should be studied further with NGS techniques in other subpopulations, both large and isolated ones, and across a range of environmental conditions, which are known to affect its detection probability (e.g. Szulkin & Sheldon 2007). Pure inbreeding rate is not informative in itself and to study its effects (and thus inbreeding depression), data on individual reproductive success and other fitness-related traits must be collected along with genetic sampling. Even if inbreeding rate is low, as in a large population, it is crucial to establish the genetic load of the population (i.e. an indicator of the frequency of lethal genes). When a population declines and inbreeding rates increase, a high genetic load is expected to accelerate extinction.

Trophic niche

The Aquatic Warbler does not live in ecological isolation. Little is known on its competitive relationships with other species. The most obvious competitor could be its kin species, the Sedge Warbler (Leisler 1988), however, niches of the two species appear to differ. It would be useful to identify the Aquatic Warbler competitors among insectivorous birds of fen mires and wet meadows, especially in less optimal habitats. Also, studies on factors governing prey availability in the species' habitats are warranted, as it is a likely factor limiting reproductive success and influencing habitat selection (Kloskowski et al. 2015).

Unknown breeding sites

In order to fully understand population processes of the species, and especially in order to plan and implement effective conservation work, a very basic requirement is the knowledge of all existing Aquatic Warbler breeding sites. Enormous progress has been made in the past 25 years. While in 1995 the occurrence of the species east of Poland was virtually unknown, today all the major breeding sites have presumably been identified (see Chapter 2.2 and **Box 3.1**). However, new smaller sites are still being discovered in Poland, Ukraine, and Belarus. These sites can be important as stepping stone habitats. Efforts should therefore also be directed at the identification of the remaining small sites, e.g. through the use of remote sensing data. Such sites, especially if remnants of a larger degraded site, can also be candidate sites for habitat restoration. In any case, their identification applies the same methods and can be combined with the identification of potential restoration sites (see Chapter 4.7).

Small breeding sites

Small breeding sites, especially when irregularly supporting breeding birds, typically receive little interest while they may provide important stop-over areas and potential stepping stones of the Aquatic Warbler recovery and therefore deserve special protection. Research on the actual suitability of such sites is important, including determination of the presence of breeding females and not only of singing males, of the presence of breeding birds throughout the entire season and not only during its early stage, and of breeding success. The quality of the small, often isolated habitat patches and the possibilities of expanding the suitable habitat area should be investigated.

Recommendations for monitoring

For continuous assessment of the population status of Aquatic Warblers and for the evaluation of the effects of management measures, regular and standardised monitoring of population and habitats is necessary. Frequency, intensity and scale of a monitoring scheme depend on population and habitat size, and on available financial resources. Key elements of a monitoring scheme in the breeding range are monitoring of population size, distribution, and trend, population state (productivity), habitat size and suitability, and ideally also demographic parameters (**Table 6.1**).

The minimum level is the monitoring of population size by regular counts of singing males. These counts should be undertaken synchronously across adjacent breeding sites during the singing activity peaks around sunset. The usual approach in Poland and Germany includes a first count in late May and a second in late June, matching the peak laying dates for early and late broods, respectively (Dyrcz et al. 1993a). At smaller sites with up to 50-100 singing males full counts should be feasible. At larger sites, a systematic sampling of randomly or systematically selected representative transects is recommended, as designed for Poland in the course of the EU-LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (see **Box 6.1**). Both protocols have their pros and cons: the new protocol is based on transects and accounts for detection probability and observation error (Oppel et al. 2014). Due to restricted resources necessary for the transect counts, they concentrate on the first part of the breeding season. This is a

Table 6.1

Overview of objectives and methods of monitoring, and related research recommended in connection with the conservation and management of breeding sites and subpopulations.

Objective	Type	Indicator	Area	Timing	Frequency/duration	Method	Results
Breeding population size, trend and distribution: full counts	status, trend, response	number of singing males	breeding sites	at least one count around each peak of singing activity for the first and second broods, synchronised between sites	regular intervals, ideally yearly, in practice every 3-4 years	counts during peak of singing activity around sunset	size, trend and distribution of breeding population
Breeding population size,trend and distribution: transect counts for large sites	status, trend, response	number of singing males	breeding sites	at least three counts around each peak of singing activity for the first and second broods, synchronised between sites	regular intervals, ideally yearly	counts along representative transects during peak of singing activity around sunset (see **Box 6.1**)	estimates of size and trend of breeding population
Breeding population state	status, response	breeding productivity	breeding sites	entire breeding season	annually, at least three years	ideal: nest success study; basic: index of feeding females	ideal: true productivity; basic: index of productivity changes
Habitat suitability	status, response	vegetation structure	breeding sites	breeding season	regular intervals, ideal: yearly	description of dominant plant species, measurement of vegetation height and litter thickness	vegetation description, mean parameter values per site
Habitat suitability	status, response	landscape structure	breeding sites	whole year	regular intervals, ideal: yearly	coverage and height of bushes and trees at a large scale (1 area unit = 10-100 ha)	large-scale mean coverage and height of woods
Habitat suitability	status, response	water level above soil surface	breeding sites	breeding season	regular intervals, ideal: yearly	ideal: gauges (read manually or with automatic data loggers); basic: measurements with ruler and assessment of soil moisture	ideal: annual water level fluctuations; basic: water level during breeding season
Demography	status, trend	age and sex ratios in autumn	stopover sites	autumn migration	long-term, ideal: yearly	mist netting, sex determination using molecular methods; valid results can only be obtained from statistical analysis across a large number of sites	index of age and sex ratio changes
Demography	status, trend	(apparent) survival	breeding sites	breeding season	annually for at least 6 years	capture-mark-recapture/ resighting (colour ringing of adults recommended)	(apparent) survival probability per year; if conducted in multiple sites: site fidelity/ exchange rates

6

Box 6.1
The new Aquatic Warbler monitoring scheme in Poland

LARS LACHMANN & JAROSŁAW KROGULEC

Mainly thanks to the LIFE projects (see **Table 5.1**) and the efforts of OTOP (Polish Society for the Protection of Birds), the national partner of BirdLife International, Poland has had the best Aquatic Warbler monitoring data of any of the key breeding range states of the species (see also Chapter 2.2). Still, the previous methods based on full counts on all Polish sites were not ideal to answer all the questions that needed to be answered, and were too labour-intensive for a long-term monitoring programme, once project funding would discontinue.

Therefore, a team of ornithologists within OTOP, supported by international experts, developed a new long-term monitoring programme for the species that will at the same time allow continuing the use of the old data collected to date (GIOŚ 2015). This new programme could set the standard for similar monitoring schemes in the other key breeding range states, Belarus and Ukraine, and has also recently been included in the government-funded Polish National Bird Monitoring Scheme.

The monitoring programme is expected to be able to answer the following questions:

1. estimate the trend of the actual national subpopulation of the species, with a statistical power to detect a 20% change within ten years;
2. give an estimate of the actual size of the national subpopulation;
3. give information on the actual number and location of occupied breeding sites in the country;
4. give information on the actual area of occupancy of the species.

In order to provide all this information, a combination of sample and full counts is needed. The basic outline of the monitoring scheme is as follows:

Every five years, a full national count is organised, covering all the known and potential Aquatic Warbler sites in the Biebrza Valley, Poleski National Park, and Chełm Marshes. A full count is carried out once during each of the two breeding peaks, i.e. between May 20 to June 10, and between June 20 to July 10, with at least a two-week interval between the two surveys. All the smaller sites (sites with up to 50 singing males, as well as potential and historical sites) are covered by full counts every year. Larger sites, however, are counted yearly using 1-km transects, randomly selected from within all the area occupied by Aquatic Warblers between 2003-2011. There are 60-80 transects in the Biebrza Valley, ten transects in the Poleski National Park, and ten transects in the Chełm Marshes. The minimum distance between the closest points of neighbouring transects is 400 m. All Aquatic Warblers seen or heard are recorded and attributed to one of three distance bands (0-25 m, 25-100 m, and >100 m). Thanks to the distance bands, it is possible to derive an estimate of the total population of the site, which can be extrapolated across all suitable habitat and compared to the full counts carried out every five years. In order to provide an estimate of variability, three replicate counts of each transect are conducted (Oppel et al. 2014), ideally on three consecutive days, but necessarily within ►

limitation because at least in part of the species' range, numbers are usually higher in the second half of June and the actual population size can only be estimated at this time (Krogulec & Kloskowski 2003). Hence, additional surveys during the late breeding season, if resources are a constraint, could be limited to sites where numbers are typically higher during the late season or where there is adverse weather (such as drought or flood) at the beginning of the season. In addition, distribution and occupancy across the whole site can only be determined through full counts. Still, the problem of full counts is that it is impossible to count the whole area simultaneously and, because the males move, there is large potential for over- or underestimation of their numbers. Therefore, a combination of full counts and transect counts is recommended (see **Box 6.1**).

In practice, in Lithuania and Germany (and Latvia, Hungary, and European Russia, if Aquatic Warblers are recorded), full counts of the national subpopulations should be standard, because the small occupied areas can be covered in a very short period of time. For the key countries, Ukraine and Belarus, it is urgently recommended that an approach similar to the Polish monitoring scheme is developed. Especially in Ukraine, available figures are of unknown representativeness, and the development of an improved monitoring is urgently needed (see Chapter 2.2). In Belarus, good progress has been made in developing a systematic monitoring of the key breeding sites (see Chapter 2.2), but a further adaptation to the Polish scheme is recommended. Habitat parameters (vegetation structure, water level, land use) should be monitored at a basic level and in a similar way to the Polish scheme along with the population counts of singing males.

Monitoring of breeding performance is recommended for the key breeding sites, small threatened subpopulations (Pomerania), and for sites where management measures have taken place. An index based on standardised regular counts of feeding females is recommended for very basic monitoring, especially in sites with high nest densities (but see the constraints of this method above). More detailed studies on nest success with a limited duration would be justified and strongly recommended where this index decreases or is generally low. Information on age ratios should already be available from the data of existing ringing activities during autumn migration. For monitoring purposes, data should be collated and analysed on a regular basis.

Box 6.1 contd seven days during the first nesting period from 20 May to 10 June every year. No counts are done during the second nesting period, in order to limit the necessary resources. The transect surveys are expected to provide the trend information that will supplement the estimate based on the full counts performed every five years. For all counts, full or transect, standard descriptions of the main habitat parameters - water level, vegetation composition and structure, and bush or tree coverage accompany the bird count data. The new transect counts have been implemented in the Biebrza Valley, Poleski National Park, and Chełm Marshes since 2011.

7 Communication as a conservation tool

7 Communication as a conservation tool

ŽYMANTAS MORKVĖNAS, VIKTAR FENCHUK & JUSTYNA KUBACKA

▲ **Fig. 7.1** **Negotiations with a farmer to postpone mowing in the area where an Aquatic Warbler singing male was located, July 2012, Nemunas Delta, Lithuania** (photo: Ž. Morkvėnas).

There are many publications stressing the importance of communication as part of the nature conservation process, which nearly became a stereotype tag without any tangible meaning. Indeed, many nature conservationists have a certain disregard for communication, giving it a 'secondary priority' in their work or treating it merely as an obligation required by formal procedures of the conservation project.

In conservation work, communication is typically segmented according to the involved stakeholder groups, such as farmers, local communities, decision makers, and the general audience. These groups differ by their interests, system of values, behaviour patterns, and relevance to the conservation object. Naturally, they differ also in terms of ways to be addressed and relevance of priority. As far as Aquatic Warbler conservation is concerned, farmers are probably the most directly involved and important target group, particularly in the areas that need regular mowing to maintain favourable breeding habitat conditions for the species. In conservation practice, it can be observed that farmers are often seen as a tool to maintain habitat, which can be triggered by financial incentives to perform certain tasks. However, defining a farmer as one of major factors shaping habitat succession would be a more exact definition. A farmer can pose a major threat to the Aquatic Warbler's breeding success (e.g. by performing early mowing), or become a major precondition for species survival in the area (e.g. by preventing habitat loss in natural succession process). Traditionally, conservationists are focused on managing different factors (e.g. hydrology, see Chapter 4.2) that have an influence on the ecosystem. Making efforts to understand the farmers' behaviour and interacting with them by communicating is of equal importance. In other words, a farmer is an important (in some cases – the most crucial) part of the ecosystem, and needs to be treated with equal importance to the conservation object through displaying an understanding of the farmer's needs and addressing them. In order to achieve a favourable conservation status of the Aquatic Warbler in farmed habitat, there should also be a focus on achieving a 'favourable conservation' status of the local farmer(s).

This chapter will reflect on experience from interactions with stakeholders based on practical work implemented in Aquatic Warbler conservation projects. This experience has been gathered in particular in Lithuania, where communication was applied as a major tool to reach conservation goals in two LIFE projects (see also Chapter 5).

The success story of communication in Lithuania

This section takes a closer look at conservation actions performed in western Lithuania between 2010 and 2015, within a dedicated project ('Baltic Aquatic Warbler - Securing Sustainable Farming to Ensure Conservation of Globally Threated Bird Species in Agrarian Landscape', LIFE09 NAT/LT/000233). It illustrates that the communication component alone can deliver important conservation achievements, contributing to the breeding success of Aquatic Warblers.

In 2012, the Aquatic Warbler subpopulation in Lithuania reached a critically low number of 60 singing males, and in 2013 an even lower number – 50 singing males. Thus, the Lithuanian Aquatic Warbler conservation team focused on protecting all areas around each individual singing male, where active nests were expected. As some singing males were found on private land managed by farmers, the conservation team approached each farmer concerned to negotiate the postponement of mowing in specific areas to late August, when the second Aquatic Warbler brood successfully left their nests (**Fig. 7.1**). This communication approach proved successful – during three seasons, all the approached farmers voluntarily agreed to postpone mowing of the targeted areas to the desired period (see **Box 7.1**). Since 2014, the Aquatic Warbler subpopulation in Lithuania has started to increase, which is assumed to partly result from the successful communication achievements. Currently, farmers, in addition to participating in special Aquatic Warbler conservation focused on agri-environmental measures under the Rural Development Programme, appear to be willing to apply local conservation measures in conventionally farmed sites, if they are appropriately informed.

The active communication work experience revealed some principles that were important in making Aquatic Warbler conservation in western Lithuania into a success story. These principles are reflected in the paragraphs below.

Proactive communication and building relationships. Stakeholder involvement is often limited to organised formal meetings, where conservationists, farmers, and other stakeholders meet on separate sides of the table to talk business. However, the proactive and informal initiation of communication towards building relationships and negotiations relying on established relationship are usually more successful. Following this approach, Aquatic Warbler conservationists in Lithuania knocked on the doors of farmers in the villages in the Nemunas Delta to introduce themselves, talk about one of Europe's rarest passerines, and – importantly – to hear the interests and concerns of local farmers, all with the aim of seeking areas of common interest and cooperation. This initiative was a very positive surprise to the farmers, who rarely see conservationists seeking friendship, and this was probably a crucial factor in building up good cooperation later. The social status of the conservation communicator is also an important aspect to consider. For example, conservationists coming to

Box 7.1

Combining 'old-fashioned' and modern tools in negotiation with farmers in Lithuania

ŽYMANTAS MORKVĖNAS

When starting Aquatic Warbler conservation in privately-owned areas at the Nemunas Delta in Lithuania (the project 'Baltic Aquatic Warbler – Securing Sustainable Farming to Ensure Conservation of Globally Threatened Bird Species in Agrarian Landscape', LIFE09 NAT/LT/000233), the conservation team faced the challenge of getting contacts of landowners in the area. The available information sources were outdated, and obtaining ownership details from authorities was not possible due to personal data confidentiality. For this reason, the team chose an old-fashioned approach: they visited villages, knocked on the doors of farmers, introduced themselves and talked about the Aquatic Warbler. Such introductory conversations initiated relationship-building and farmers also identified their farming plots on the map. In addition, they provided further links in the chain, indicating the houses of other farmers neighbouring the field with singing males. After approximately two weekends, the conservation team had established contacts and mapped nearly all the area of concern, covering approximately 700 ha.

The gathered contact information about farmed land plots was further transferred into a map using the ArcGis online tool and a spatial database was created (**Fig. 7.2**). This online tool, available for smartphones and tablets, was highly useful for organising a rapid communication process and postponing mowing at sites where Aquatic Warbler singing males were observed. Singing males recorded by bird monitoring experts were added to the map and the negotiation team of the project could immediately see their locations and identify individual farmers managing those areas. A quick phone call or a visit to discuss postponing the mowing in the defined area resulted in the successful breeding of a lot of Aquatic Warblers. The online tool offered very quick information exchange, which is crucial in the survival race where farmers rush to collect animal feed and Aquatic Warblers raise their young.

7

▲ **Fig. 7.2**
An ArcGis Online interactive map, serving as a tool for rapid identification of the farmer managing an area in western Lithuania.

rural areas from a distant city might be perceived as outsiders who do not know how farming works, and at the same time as those who are closer to the politicians. The attitude towards the communicator might also be determined by factors such as gender, area of origin, or profession. These things need to be considered during the process of putting together a communication team.

Establishing traditions that connect conservationists and farmers as a joint team. It is important to maintain and further strengthen the established relationships. This can be done by bringing conservationists and local stakeholders (farmers, opinion leaders, local authorities, youth, and children) into joint happenings with a shared interest, which sets an important informal context. A good example might be the annual Aquatic Warbler welcoming festival, organised outdoors in the farming fields, where conservationists told stories about the bird and stimulated discussion on how mowing would be performed in the coming season, where cooperation would be needed, and how conservationists would inform farmers about breeding birds. Further, farmers were engaged in collective birdwatching and learning how to recognise the Aquatic Warbler (**Fig. 7.3**). The contacts established with stakeholders were maintained by organising round table meetings (**Fig. 7.4**) to discuss the design of special agri-environmental measures. In addition to these activities, the conservationists at the Nemunas Delta maintained contact with farmers by periodically sending them news and updates by post. Recently, they also made special Aquatic Warbler flags, which are distributed to those farmers who are committed to the bird's conservation (**Fig. 7.5**). Hanging this flag at the house on an Aquatic Warbler welcoming day will show the farmers how special they are and build team feeling. This com-

Fig. 7.3
Observation of Aquatic Warblers with the local community at a special bird welcoming event in Lithuania, May 2012 (photo: Ž. Morkvėnas).

Fig. 7.4
(middle) A round table discussion with farmers about cooperation during the mowing season, Lithuania, June 2013 (photo: Ž. Morkvėnas).

Fig. 7.5
(bottom) In Lithuania, farmers who undertake conservation measures in their fields receive a special Aquatic Warbler flag (photo: Ž. Morkvėnas).

munication approach proved to be highly effective and create natural and long-lasting relationships with targeted stakeholders.

Stimulating motivation to conserve the Aquatic Warbler. One of the basic elements of the communication strategy for Aquatic Warbler conservation in Lithuania was to make this bird a 'celebrity', both in the region and across the country. This was expected to both facilitate obtaining support for its conservation and raise interest in the bird itself. It was also supposed to increase its importance to the farmers managing Aquatic Warbler breeding grounds and make them more willing to be explicitly associated with the species. Another important approach of the communication strategy was – where appropriate – to place the farmer in a communication frontline. In other words, instead of stressing the conservationist efforts and achievements, to focus on the farmers' efforts in conservation, and associate conservation successes with the farmer where possible. This approach has two benefits. Firstly, in the media farmers are illustrated as an important precondition for the bird's survival, and not as a threat, which sets a better basis from which to seek cooperation. Of course, farming threats were also being communicated to the target audiences, but the overall context showed farmers in a positive light. Secondly, making farmers into heroes in the local media enhances their self-esteem (which is a basic human need) and makes them proud of themselves, which drives them towards contributing to conservation.

It is also crucial to have permanently open ears to what motivates a stakeholder

► **Fig. 7.6**
The street art painting on a wall of the pumping station in Tulkiaragė, Nemunas Delta, Lithuania (photo: Ž. Morkvėnas).

▼ **Fig. 7.7**
A Lithuanian stamp depicting Aquatic Warblers.

to protect the Aquatic Warbler. It is often assumed that the most efficient (if not the only real argument) stimulus to trigger conservation motivation is economic interest (e.g. a special payment for conservation efforts implemented). Indeed, this is an important factor and farmers are usually very practical people. But practical experience and various studies have shown that social and ethical considerations can also be very powerful motivators. While triggering them might be more challenging compared to a straightforward economic stimulus, they also have longer-lasting effects and create a stronger bond based on the system of values. Telling farmers about the Aquatic Warbler's life, or about motivation of others, can stimulate positive attitudes towards conservation. People usually support ideas and stories in which they recognise familiar features. People are social – they want to belong to groups of other people sharing similar interests. Aquatic Warbler conservation can be one such interest. Understanding the 'social portrait' of the stakeholder is very important in order to decide which conservation stimulus to offer. A good resource to understand and pick the right engagement strategies could be the book 'What makes people tick' by Chris Rose (Rose 2011, http://threeworlds.campaignstrategy.org). The communication strategy of the current Aquatic Warbler conservation project in Lithuania and Belarus ('LIFE MagniDucatusAcrola – Stepping stones towards ensuring the long-term favourable conservation status of Aquatic Warbler in Lithuania and Belarus', LIFE15 NAT/LT/001024) is based on the model introduced in the book, and its experience will be shared in future publications.

Apart from direct communication actions, in Lithuania the Aquatic Warbler has been made a flagship species through artwork. An example is the Tulkiaragė trail in the Nemunas Delta, where an abandoned pumping station has been restored and converted to a birdwatching tower and an education facility, becoming a tourist attraction. One of its main walls depicts the largest Aquatic Warbler in the world (**Fig. 7.6**) and is often photographed by tourists coming to the area. In addition, in 2013 the Lithuania Post, as part of the tradition to present endangered animal species to the public through postage stamps, released a stamp showing the Aquatic Warbler, designed by the artist Eglė Ratkutė (**Fig. 7.7**).

How an unknown bird became the symbol of Belarusian nature

It was only in 1995-1996 that key Aquatic Warbler breeding sites were discovered in Belarus (see **Box 3.1**). Urgent conservation actions needed to be planned and implemented, so the first nature conservation organisation of Belarus – APB-BirdLife Belarus – was established in 1998, taking the Aquatic Warbler as its logo (**Fig. 7.8**). Since then, the Aquatic Warbler has become not only the symbol of the largest nature conservation organisation in Belarus, but also the symbol of Belarusian mires and nature conservation.

The promotion of the Aquatic Warbler went in parallel with conservation measures. A great boost towards recognising the significance of mires and the birds was given by a popular documentary by Dr Igor Byshnev 'The World of the Aquatic Warbler', released in 1998, and a number of social adverts on the Belarusian TV dedicated to the conservation of mires and the flagship species, including the Aquatic Warbler. This was supported by one of the first bird stamps in Belarus, issued in 1998 and followed by another one in 2002 (**Fig. 7.9**).

Starting from 1998, a number of large projects were carried out in Belarus for planning and implementing conservation measures at key Aquatic Warbler breeding sites (see Chapters 4.2-4.7). Each of these had a communication component targeting various audiences. An important development was a special event at the Sporava Nature Reserve – 'Sporava scything championship' (**Fig. 7.10**), which started its history in 2007, becoming an international festival with broad recognition nationwide. This scything championship is now held annually in the Sporava Reserve, promoting the Aquatic Warbler, as well as fen mires and their conservation needs.

The Aquatic Warbler features on the logos of the Sporava and Zvaniec nature reserves (**Fig. 7.11**). In addition, following an initiative by the APB, districts of Belarus chose their flagship birds. In 2017, the Aquatic Warbler was officially elected as a bird-symbol of the Drahicyn district, where the world's largest breeding site of the Aquatic Warbler, the famous Zvaniec Mire is found (**Fig. 7.12**).

Today, there is no doubt about the need to conserve Belarusian mires. And largely this is thanks to the little brown bird, which has become a nationwide hero and a well-known flagship bird species in Belarus.

► **Fig. 7.8**
The logo of APB-BirdLife Belarus (http://ptushki.org), the leading nature conservation non-governmental organisation in Belarus.

▼ **Fig. 7.9**
As a result of the extensive cooperation between APB-BirdLife Belarus and Belpost, the Aquatic Warbler appeared on Belarusian postal stamps.

◄▲ **Fig. 7.10**
The national scything championship at the Sporava Nature Reserve in Belarus (photo: A. Ivanova).

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◄ **Fig. 7.11**
The Aquatic Warbler is in the logo of the Sporava Nature Reserve in Belarus.

► **Fig. 7.12**
In Belarus, the Aquatic Warbler was selected as the flagship species of the Drahicyn district, which holds the largest breeding site in the world.

Communication actions in Poland

▲ **Fig. 7.13**
A board welcoming visitors to the Trzcianne commune, an administrative unit in the Biebrza Valley. The text reads 'Trzcianne commune. Welcome to the land of the Aquatic Warbler' (photo: F. Tanneberger).

In Poland, communication and promotion activities related to the Aquatic Warbler were performed chiefly in two LIFE projects, 'Conserving *Acrocephalus paludicola* in Poland and Germany' 2005-2011 (LIFE05 NAT/PL/000101) and 'Biomass use for Aquatic Warbler – Facilitating Aquatic Warbler (*Acrocephalus paludicola*) habitat management through sustainable systems of biomass use' 2010-2015 (LIFE09 NAT/PL/000260). Unlike in Lithuania, however, communication was not the main goal in either of these projects. In both projects, a website was set up, information boards were installed at every project site, and promotional materials such as leaflets (in the first Polish LIFE project only, c. 200,000 leaflets), stickers, pin-badges, posters, newsletters, calendars, notebooks, and a film were produced. Where appropriate, information was disseminated in three languages, corresponding to the target audience: Polish, German, and English. Special care was given to build good relationships with journalists by organising press conferences, special tours for journalists to enable them observing and listening to the Aquatic Warbler, and sending out press releases (P. Szałański pers. comm.).

Following advocacy during the project 'Conserving *Acrocephalus paludicola* in Poland and Germany', one of the three administrative units that are found in the Biebrza Valley, the Trzcianne commune, took the Aquatic Warbler as its logo, and has since advertised itself as 'the land of the Aquatic Warbler' (**Fig. 7.13**).

Actions spreading and raising public awareness included indoor and outdoor classes for children, and an open day in the pelleting facility in Trzcianne (Biebrza Valley), attended by around 200 people. Project stands were set up during local events in the Biebrza Valley and the Lublin voivodeship, promoting the projects among adults through leaflets, quizzes, and distributing pellet samples, as well as educational games and painting contests for children (**Fig. 7.14**, **7.15**, **7.16**).

Independently of these projects, a haymaking day has regularly been held in the Biebrza Valley since the early 2000s, featuring a scything contest and attracting many people (**Fig. 7.17**). The aim of the event is to save the tradition of mowing wet meadows for hay and to popularise habitat management on the mires. It takes place during late summer or early autumn and is organised by the Trzcianne commune and the Biebrza National Park. The contest attracts local farmers, local government representatives, and visitors from abroad. Contestants mow a 100 m long stretch of fen with a traditional scythe. For several years, OTOP (the Polish Society for the Protection of Birds) has had its stand during the event, to explain and promote mowing for the conservation of the Aquatic Warbler.

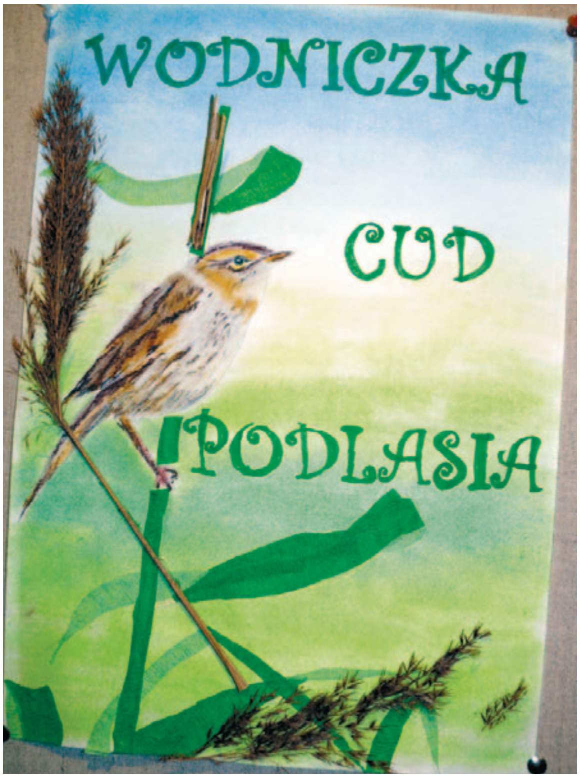
7

◄ **Fig. 7.14**
The LIFE projects in Poland dedicated to Aquatic Warbler conservation included educational activities targeted at children (photo: L. Lachmann).

▼ **Fig. 7.15**
(left) One of the pictures created during a painting contest held in 2009 among children in the Biebrza Valley (photo: L. Lachmann).

▼ **Fig. 7.16**
(right) Promotion of the Aquatic Warbler was part of the LIFE projects in Poland (photo: M. Flade).

► **Fig. 7.17**
A scything contest, held annually in the Biebrza Valley, September 2008 (photo: L. Lachmann).

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Abramchuk, M. (2015) Impact of large tracked mowers on vegetation structure and functional plant diversity of fens in the Biebrza National Park. MSc thesis. 44 p. Warsaw: University of Warsaw.

Allen, S.S. (1966) Chemical aspects of heather burning. Journal of Applied Ecology 1: 347-367.

Andueza, M., Tamayo-Uria, I. & Arizaga, J. (2014) Estudio preliminar sobre el uso del espacio por parte del carricerín cejudo *Acrocephalus paludicola* (Vieillot, 1817) en la marisma de Jaizubia (Txingudi, Gipuzkoa) durante la migración posnupcial. [Preliminary study on the habitat use of the Aquatic Warbler *Acrocephalus paludicola* (Vieillot, 1817) in the marsh of Jaizubia (Txingudi, Gipuzkoa) during post-nuptial migration.] Munibe 62: 153-160. (in Spanish)

Araujo, M.B. & New, M. (2006) Ensemble forecasting of species distributions. Trends in Ecology and Evolution 22: 42-47.

Arbeiter, S. (2009) Aktionsraum und Habitatnutzung des Seggenrohrsängers (*Acrocephalus paludicola*) im Überwinterungsgebiet Djoudj-Nationalpark in Senegal. [Activity range and habitat use of the Aquatic Warbler (*Acrocephalus paludicola*) at the wintering site Djoudj National Park, Senegal] MSc thesis. Eberswalde: Hochschule für Nachhaltige Entwicklung. (in German)

Arbeiter, S. & Tegetmeyer, C. (2011) Home range and habitat use by Aquatic Warblers *Acrocephalus paludicola* on their wintering grounds in northwestern Senegal. Acta Ornithologica 46: 117-126.

Arizaga, J., Unamuno, E., Clarabuch, O. & Azkona, A. (2013) The impact of an invasive exotic bush on the stop-over ecology of migrant passerines. Animal Biodiversity and Conservation 36: 1-11.

Atienza, J.C., Pinilla, J. & Justribó, J.H. (2001) Migration and conservation of the Aquatic Warbler *Acrocephalus paludicola* in Spain. Ardeola 48: 197-208.

AWCT (Aquatic Warbler Conservation Team) (1999) World population, trends and conservation status of the Aquatic Warbler *Acrocephalus paludicola*. Vogelwelt 120: 65-85.

Axell, H.E. (1982) Control of reeds (*Phragmites communis*) at Minsmere, England. In: Managing wetlands and their birds (ed. by O.A. Scott), pp. 44-50. Slimbridge: International Waterfowl Research Bureau.

Backman, J. & Alerstam, T. (2003) Orientation scatter of free-flying nocturnal passerine migrants: components and causes. Animal Behaviour 65: 987-996.

Baillie, S.R. (2001) The contribution of ringing to the conservation and management of bird populations: a review. Ardea 89: 167-184.

Bakker, J.P., Elzinga, J.B. & de Vries, Y. (2002) Effects of long-term cutting in a grassland system: perspectives for restoration of plant communities on nutrient-poor soils. Applied Vegetation Science 5: 107-120.

Báldi, A. & Kisbenedek, T. (1999) Species-specific distribution of reed-nesting passerine birds across reed-bed edges: effects of spatial scale and edge type. Acta Zoologica Academiae Scientiarum Hungaricae 45: 97-114.

Balsevičius, A. & Narijauskas, R. (2015) Diversity, distribution of vegetation and suitability for breeding of the Aquatic Warbler in Šyša polder. Report. 38 p. Marijampolė.

Balsevičius, A., Matulevičiūtė, D. & Narijauskas, R. (2015a) Diversity, distribution of vegetation and suitability for breeding of the Aquatic Warbler in Tyrai. Report. 17 p. Marijampolė.

Balsevičius, A., Narijauskas, R., Blockuvienė, A. & Jarmalavičienė, K. (2015b) Diversity, distribution of vegetation and suitability for breeding of the Aquatic Warbler in Dambavaragis meadows and Kiaulyčia Swamp (Žuvintas Biosphere Reserve). Report. 74 p. Marijampolė.

Bambalov, N., Tanovitskaya, N., Kozulin, A. & Rakovich, V. (2017) Belarus. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 288-298. Stuttgart: Schweizerbart Science Publishers.

Banaszuk, P., Kamocki, A.K. & Zarzecki, R. (2016) Mowing with invasive machinery can affect chemistry and trophic state of rheophilous mire. Ecological Engineering 86: 31-38.

Bargain, B. (2003) Étude du milieu fréquenté par le Phragmite aquatique en baie d'Audierne; radio-pistage 2001 et 2002. Rapport d'activité. [Study of the habitat used by the Aquatic Warbler in Audierne Bay; radio-tracking 2001 and 2002] 16 p. Brest: Bretagne Vivante-SEPNB. (in French)

Battin, J. (2004) When good animals love bad habitats: ecological traps and the conservation of animal populations. Conservation Biology 18: 1482-1491.

BEF (Baltic Environmental Forum) (2013) Šyšos polderio studija. [Šyša polder study] 31 p. https://docs.wixstatic.com/ugd/440491_0a1e079a43d64e88ab0222995aa48f42.pdf; accessed 01/2018. (in Lithuanian)

BEF (Baltic Environmental Forum) (2017) Project 'Securing sustainable farming to ensure conservation of globally threatened bird species in agrarian landscape' LIFE09 NAT/LT/000233. Final report covering the project activities from 01/09/2010 to 31/09/2015. 113 p. Vilnius: BEF Lithuania.

Bellebaum, J. & Koffijberg, K. (2018) Present agri-environment measures in Europe are not sufficient for the conservation of a highly sensitive bird species, the Corncrake Crex crex. Agriculture, Ecosystems and Environment 257: 30-37.

Bellebaum, J. & Tanneberger, F. (2011) EU-LIFE-Projekt 'Conserving *Acrocephalus paludicola* in Poland and Germany' (LIFE05NAT/PL/000101). Managementplan Projektgebiet Peenetal. [EU-LIFE project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (LIFE05NAT/PL/000101). Management plan project site Peene valley] Unpublished report. 53 p. (in German)

Bellebaum, J. & Tanneberger, F. (2018) Schutz von Seggenrohrsänger, Wachtelkönig und Brenndoldenwiesen am Beispiel des Unteren Odertals. [The Lower Oder Valley as example for the protection of Aquatic Warbler, Corncrake, and alluvial meadows of the Cnidion dubii] Naturschutz und Biologische Vielfalt 161: 1-140. (in German)

References

Bender, D.J., Contreras, T.A. & Fahrig, L. (1998) Habitat loss and population decline: a meta-analysis of the patch size effect. Ecology 79: 517-533.

Biebrza National Park (2015) Sprawozdanie finansowe za rok 2014. [Financial Report 2014] Monitor Sądowy i Gospodarczy 183/2015 (4814), poz. 14086. http://www.krs-online.com.pl/msig/2015/14086.pdf; consulted in 03/2018. (in Polish)

Billeter, R., Hooftman, D.A.P. & Diemer, M. (2003) Differential and reversible responses of common fen meadow species to abandonment. Applied Vegation Science 6: 3-12.

BirdLife International (2008) Development and revision of action plans for six threatened bird species in the EU. Final report to the EU's N2K Group EEIG. Unpublished report.

BirdLife International (2015) *Acrocephalus paludicola*. The IUCN Red List of Threatened Species 2015: e.T22714696A84642979. http://dx.doi.org/10.2305/IUCN.UK.2015.RLTS.T22714696A84642979.en; consulted in 07/2016.

BirdLife International (2017a) Important Bird Areas factsheet: Balota Zvaniec. http://datazone.birdlife.org/site/factsheet/balota-zvaniec-iba-belarus; consulted in 10/2017.

BirdLife International (2017b) Towards a new European food and land-use policy. Position paper. October 2017. 14 p. Brussels: BirdLife International.

BirdLife International and CMS (2006) Priority projects list. http://cms.int/aquatic-warbler/sites/default/files/document/MOS1_Doc_08_Priority_Projects_List_0.pdf; consulted in 03/2018.

Birkhead, T.R. (1993) Avian mating systems: The Aquatic Warbler is unique... Trends in Ecology and Evolution 8: 390-391.

Blaize, C., Fournier, J. & Jiguet, F. (2014) Les captures de Phragmites aquatiques en France, 2012. Plan national d'actions du phragmite aquatique 2010-2014. [Catches of Aquatic Warbler in France, 2012. National Aquatic Warbler Action Plan 2010-2014] 19 p. Nantes, Brest: DREAL Bretagne, Bretagne Vivante-SEPNB. (in French)

Bokdam, J., van Braeckel, A., Werpachowski, C. & Znaniecka, M. (eds) (2002) Grazing as a conservation management tool in peatland. Report of a workshop held 22-26 April 2002 in Goniądz (PL). 105 p. Warsaw: WWF Poland.

Borger, G.J. (1992) Draining – digging – dredging; the creation of a new landscape in the peat areas of the low countries. In: Fens and bogs in the Netherlands: Vegetation, history, nutrient dynamics and conservation (ed. by J.T.A. Verhoeven), pp. 131-171. Geobotany 18. Dordrecht: Kluwer.

Bradbury, J.W. & Vehrencamp, S.L. (1998) The principles of animal communication. 882 p. Sunderland, Massachusetts: Sinauer Associates.

Briedis, M. & Keišs, O. (2016) Extracting historical population trends using archival ringing data – an example: the globally threatened Aquatic Warbler. Journal of Ornithology 157: 419-425.

Brunel, E., Cadou, D., Kerbiriou, C. & Le Viol, I. (1998) Les Dolichopodidés et les Syrphidés des îles de la réserve de Biosphère d'Iroise (Finistère, France): premier inventaire (Diptera). [Dolichopodideae and Syrphideae of the islands in the Biosphere Reserve d'Iroise (Finistère, France) : initial inventory (Diptera)] Bulletin de la société entomologique de France 103: 57-62. (in French)

Buchanan, G.M., Lachmann, L., Tegetmeyer, C., Oppel, S., Nelson, A.D. & Flade, M. (2011) Identifying the potential wintering sites of the globally threatened Aquatic Warbler *Acrocephalus paludicola* using remote sensing. Ostrich 82: 81-85.

Budka, M., Marczakiewicz, P., Lachmann, L. & Krogulec, J. (2013) Plan zarządzania dla obszaru Biebrzański Park Narodowy [Management plan for the Biebrza National Park]. 169 p. Osowiec-Twierdza: Biebrza National Park. (in Polish)

Buermann, W., Saatchi, S., Smith, T.B., Zutta, B.R., Chaves, J.A., Milá, B. & Graham, C.H. (2008) Predicting species distributions across the Amazonian and Andean regions using remote sensing data. Journal of Biogeography 35: 1160-1176.

Burkart, M., Dierschke, H., Hölzel, N., Nowak, B. & Fartmann, T. (2004) Molinio-Arrhenatheretea (E1) – Futter- und Streuwiesen feucht-nasser Standorte und Klassenübersicht Molinio-Arrhenatheretea. [Molinio-Arrhenatheretea (E1) – fodder and litter meadows of moist to wet sites and class overview Molinio-Arrhenatheretea] Synopsis der Pflanzengesellschaften Deutschlands 9: 1-103. (in German)

Busse, P. (1974) Biometrical methods. Notatki Ornitologiczne 15: 114-126.

Catchpole, C.K. (1983) Variation in the song of the Great Reed Warbler *Acrocephalus arundinaceus* in relation to mate attraction and territorial defence. Animal Behaviour 31: 1217-1225.

Catchpole, C.K. & Leisler, B. (1989) Variation in the song of the Aquatic Warbler *Acrocephalus paludicola* in response to playback of different song structures. Behaviour 108: 125-138.

Catchpole, C.K. & Leisler, B. (1996) Female Aquatic Warblers (*Acrocephalus paludicola*) are attracted by playback of longer and more complicated songs. Behaviour 133: 1153-1164.

Chenaval, N., Lorrillière, R., Dugué, H. & Doxa, A. (2011) Phénologie et durée de halte migratoire de quatre passereaux paludicoles en migration post-nuptiales en estuaire de La Loire. [Phenology and migratory stopover duration of four passerines in post-breeding migration in the Loire Estuary.] Alauda 79: 149-156. (in French)

Ciaciura, M. & Stępień, E. (1998) O ochronie stanowisk woskownicy europejskiej *Myrica gale* L. na Bagnach Rozwarowskich. [On the protection of Bog Myrtle *Myrica gale* L. habitats at the Rozwarowo Marshes] Chrońmy Przyrodę Ojczystą 54:14-20. (in Polish)

Clarke, A.L., Sæther, B.-E. & Røskaft, E. (1997) Sex biases in avian dispersal: a reappraisal. Oikos 79: 429-438.

Claßen, A., Hirler, A. & Oppermann, R. (1996) Auswirkungen unterschiedlicher Mähgeräte auf die Wiesenfauna in Nordost-Polen. Untersucht am Beispiel von Amphibien und Weißstorch. [Impacts of different mowing devices on the meadow fauna in Northeast-Poland. Analysed on the example of amphibians and White Stork] Naturschutz und Landschaftsplanung 28: 139-144. (in German)

Claßen, A., Kapfer, A. & Luick, R. (1993) Einfluss der Mahd mit Kreisel- und Balkenmäher auf die Fauna von Feuchtgrünland. [Influence of mowing with rotary mower and cutter bar on the fauna of wet grassland] Naturschutz und Landschaftsplanung 25: 217-221. (in German)

Convention on the Conservation of Migratory Species of Wild Animals (CMS) (2015) Secretariat report. Third Meeting of the Signatories of the Memorandum of Understanding Concerning Conservation Measures for the Aquatic Warbler. http://cms.int/aquatic-warbler/sites/default/files/document/Doc_05_Report%20from%20the%20Secretariat.pdf; consulted in 03/2018.

Convention of Biological Diversity (CBD) (1992) https://www.cbd.int/; consulted in 10/2017.

Couwenberg, J., Thiele, A., Tanneberger, F., Augustin, J., Bärisch, S., Dubovik, D., Liashchynskaya, N., Michaelis, D., Minke, M., Skuratovich, A. & Joosten, H. (2011) Assessing changes in greenhouse gas emissions from peatlands using vegetation as a proxy. Hydrobiologia 674: 67-89.

Cowie, N.R., Sutherland, W.J., Ditlhogo, M.K.M. & James, R. (1992) The effects of conservation management of reed beds. II. The flora and litter disappearance. Journal of Applied Ecology 29: 277-284.

Cramp, S. & Brooks, D.J. (eds) (1992) The Birds of the Western Palearctic, Volume 6: Warblers. 736 p. Oxford: Oxford University Press.

Croteau, E.K., Lougheed, S.C., Kranitz, P.G., Mahony, N.A., Walker, B.L. & Boag, P.T. (2007) Genetic population structure of the sagebrush Brewer's Sparrow, *Spizella breweri breweri*, in a fragmented landscape at the northern range periphery. Conservation Genetics 8: 1453-1463.

Crouzier, P. (2003) Phragmite aquatique. [Aquatic Warbler] In: Atlas des oiseaux nicheurs de Rhônes-Alpes [Atlas of the breeding birds of the Rhônes-Alpes] (ed. by Collectif des Ornitologues Rhonalpins), p. 204. Cora. (in French)

Dale, S. (2001) Female-biased dispersal, low female recruitment, unpaired males, and the extinction of small and isolated bird populations. Oikos 92: 344-356.

Danner, H.S., Renes, J., Toussaint, B., van de Ven, G.P. & Zeiler, F.D. (eds) (2005) Polder pioneers. The influence of Dutch engineers on water management in Europe, 1600–2000. Netherlands Geographical Studies 338. 177 p. Utrecht: KNAG.

de By, R.A. (1990) Migration of Aquatic Warbler in western Europe. Dutch Birding 12: 165-181.

Deák, B., Valkó, O., Török, P., Kelemen, A., Tóth, K., Miglécz, T. & Tóthmérész, B. (2015) Reed cut, habitat diversity and productivity in wetlands. Ecological Complexity 22: 121-125.

Derr, J.F. (2008) Common Reed (*Phragmites australis*) response to mowing and herbicide application. Invasive Plant Science and Management 1: 12-16.

Dia, A., Dieng, P.M., Diop, A., Diouf, M. & Fall, S.M. (2002) Plan d'aménagement et de gestion du Parc National des Oiseaux du Djoudj (PNOD) et de sa périphérie. [Development and management plan of the Djoudj Bird National Park (PNOD) and its periphery] Unpublished report. 147 p. (in French)

Ditlhogo, M.K.M., James, R., Laurence, B.R. & Sutherland, W.J. (1992) The effects of conservation management of reed beds. I. The invertebrates. Journal of Applied Ecology 29: 265-276.

Dittberner, H. & Dittberner, W. (1976) Der Seggenrohrsänger im Bezirk Frankfurt/Oder. [The Aquatic Warbler in the district Frankfurt/Oder] Falke 23: 78-81. (in German)

Donald, P.F. (2007) Adult sex ratios in wild bird populations. Ibis 149: 671-692.

Dormann, C.F., Schweiger, O., Arens, P., Augenstein, I., Aviron, S., Bailey, D., Baudry, J. & 33 others (2008) Prediction uncertainty of environmental change effects on temperate European biodiversity. Ecology Letters 11: 235-244.

Driessen, N., Albrech, J., Bonn, S., Bylebyl, K., Poschlod, P., Sander, U., Sound, P. & Veith, M. (2006) Nachhaltige Entwicklung xerothermer Hanglagen am Beispiel des Mittelrheintals. [The Middle Rhine Vally as an example for sustainable development of xerotherm slopes] Natur und Landschaft 81: 130-137. (in German)

Dyrcz, A. (1989) Polygyny in the Aquatic Warbler *Acrocephalus paludicola*. Ibis 131: 298-300.

Dyrcz, A. (1993) Nesting biology of the Aquatic Warbler *Acrocephalus paludicola* in the Biebrza marshes (NE Poland). Vogelwelt 114: 2-15.

Dyrcz, A. & Czeraszkiewicz, R. (1993) Liczebność, zagrożenia i sposoby ochrony populacji lęgowej wodniczki (*Acrocephalus paludicola*) w Polsce. [Number, threats and conservation options for the breeding population of the Aquatic Warbler (*Acrocephalus paludicola*) in Poland] Notatki Ornitologiczne 34: 231-246. (in Polish)
Dyrcz, A. & Zdunek, W. (1993a) Breeding ecology of the Aquatic Warbler *Acrocephalus paludicola* on the Biebrza marshes, northeast Poland. Ibis 135: 181-189.
Dyrcz, A. & Zdunek, W. (1993b) Breeding statistics of the Aquatic Warbler *Acrocephalus paludicola* on the Biebrza Marshes, northeast Poland. Journal of Ornithology 134: 317-323.
Dyrcz, A., Sauer-Gürth, H., Tkadlec, E. & Wink, M. (2004) Offspring sex ratio variation in the Aquatic Warbler *Acrocephalus paludicola* in relation to brood size and mortality. Ibis 146: 269-280.
Dyrcz, A., Wink, M., Backhaus, A., Zdunek, W., Leisler, B. & Schulze-Hagen, K. (2002) Correlates of multiple paternity in the Aquatic Warbler (*Acrocephalus paludicola*). Journal of Ornithology 143: 430-439.
Dyrcz, A., Wink, M., Kruszewicz, A. & Leisler, B. (2005) Male reproductive success is correlated with blood parasite levels and body condition in the promiscuous Aquatic Warbler (*Acrocephalus paludicola*). The Auk 122: 558-565.
Dyrcz, A., Zdunek, W. & Schulze-Hagen, K. (2011) Increased male singing in response to predator presence mayrepresent reproductive investment in a promiscuous species, the Aquatic Warbler *Acrocephalus paludicola*. Acta Ornithologica 46: 97-100.
EEA (European Environment Agency) (2014) Projected changes in annual mean temperature and annual precipitation. https://www.eea.europa.eu/data-and-maps/figures/projected-change-in-annual-mean;consulted in 12/2017.
EEA (European Environment Agency) (2017a) Environmental indicator report 2017 – In support to the monitoring of the 7th Environment Action Programme, EEA report No 21/2017, European Environment Agency. https://www.eea.europa.eu/airs/2017/natural-capital/eutrophication-of-terrestrial-ecosystems; consulted in 01/2018.
EEA (European Environment Agency) (2017b) Climate change impacts and adaptation. https://www.eea.europa.eu/soer-2015/europe/climate-change-impacts-and-adaptation; consulted in 12/2017.
Engloner, A.I. (2009) Structure, growth dynamics and biomass of Reed (*Phragmites australis*) – a review. Flora 204: 331-346.
Essl, F. & Steiner, G.M. (2017) Austria. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 257-265. Stuttgart: Schweizerbart Science Publishers.
Essl, F., Dullinger, S., Moser, D., Rabitsch, W. & Kleinbauer, I. (2012) Vulnerability of mires under climate change: implications for nature conservation and climate change adaptation. Biodiversity and Conservation 21: 655-669.
European Commission (2015) LIFE and climate change mitigation. 92 p. Luxembourg: Publications Office of the European Union.
Falińska, K. (1999) Seed bank dynamics in abandoned meadows during a 20-year period in the Białowieża National Park. Journal of Ecology 87: 461-475.
Fenchuk, V.A. & Cherkas, N.D. (2009) Современное состояние вертлявой камышевки *Acrocephalus paludicola* в Национальном парке Беловежская пуща. Оценка численности, угрозы и рекомендации. [Current state of the Aquatic Warbler *Acrocephalus paludicola* in National Park Belovezhskaya pushcha. Number estimates, threats and recommendations] Beloveszskaya pushcha issledovaniya 13: 118-125. (in Russian)
Findorff, J.C. (1764, published 1937) Beiträge und Fragmente zu einem Moorkatechismus / von Jürgen Christian Findorff und Anmerkungen von F. Brüne, K. Lilienthal und F. Overbeck. [Contributions and fragments to a peatland catechism from Jürgen Christian Findorff with remarks from F. Brüne, K. Lilienthal and F. Overbeck] 69 p. Oldenburg: Stalling. (in German)
Flade, M. (2008) Searching for wintering sites of the Aquatic Warbler *Acrocephalus paludicola* in Senegal and Mauritania 13th to 26th January 2008. Unpublished report. 94 p. Aquatic Warbler Conservation Team.
Flade, M. & Lachmann, L. (2008) International Species Action Plan for the Aquatic Warbler *Acrocephalus paludicola*. 74 p. Cambridge: BirdLife International.
Flade, M., Diop, I., Haase, M., Le Nevé, A., Oppel, S., Tegetmeyer, C., Vogel, A. & Salewski, V. (2011) Distribution, ecology and threat status of the Aquatic Warblers *Acrocephalus paludicola* wintering in West Africa. Journal for Ornithology 152: 129-140.
Flousek, J. & Cepák, J. (2013) Status of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*) in the Czech Republic. Sylvia 49: 1-20.
Foppen, R.P.B., ter Braak, C.J.F., Verboom, J. & Reijnen, R. (1999) Dutch Sedge Warblers *Acrocephalus schoenobaenus* and West-African rainfall: empirical data and simulation modeling show low population resilience in fragmented marshlands. Ardea 87: 113-127.
Foucher, J. (2009) Evaluation de la quantité alimentaire disponible pour les passereaux paludicoles en halte migratoire, exemple de la roselière de Donges est en Loire-Atlantique (44), Rapport de stage. [Evaluation of the amount of food available for migrant passerines in migratory stopover, example of the Donges Est reedbed in Loire-Atlantique (44), Report of internship.] 48 p. Lyon: University of Lyon. (in French)
Foucher, J. (2013) Bilan et analyse des données de la station de baguage de Donges Est pour l'année 2013. [Review and analysis of the Donges East banding station data for the year 2013] 24 p. Cordemais: Association ACROLA. (in French)

Foucher, J. & Dugué, H. (2012) Bilan et analyse des données de la station de baguage de Donges Est pour l'année 2012. [Review and analysis of the Donges East banding station data for the year 2012] 35 p. Cordemais: Association ACROLA. (in French)

Foucher, J., Boucaux, M., Giraudot, E., André, A., Lorrillière, R. & Dugué, H. (2013) Nouveaux sites d'hivernage du Phragmite aquatique *Acrocephalus paludicola*. [New wintering sites of the Aquatic Warbler *Acrocephalus paludicola*] Ornithos 20: 1-9. (in French)

Foucher, J., Dugué, H., Ożarowska, A., Wojczulanis-Jakubas, K., Heinrich, F., Lefebvre, M. & Archer, E. (2011) Bilan et analyse des données de la station de baguage de Donges Est pour l'année 2011. [Review and analysis of the Donges East banding station data for the year 2011] 52 p. Cordemais: Association ACROLA. (in French)

Foucher, J., Jaguenet, E., Boucaux, M., Giraudot, E., Archer, E., Jeanneau, B., Dziarska-Pałac, J., Lachaud, A. & Dugué H. (2014) Résultat de 10 ans de suivi du Phragmite aquatique *Acrocephalus paludicola* à la station de baguage de Donges dans l'Estuaire de la Loire. [Result of 10 years of monitoring the Aquatic Warbler *Acrocephalus paludicola* at the Donges Ringing Station in the Loire Estuary.] Alauda 82: 269-282. (in French)

Fourcher, J., Lorrilliere, R. & Dugué, H. (2010) Bilan et analyse des données de la station de baguage de Donges Est pour l'année 2010. [Review and analysis of the Donges East banding station data for the year 2010] 45 p. Cordemais: Association ACROLA. (in French)

Frankham, R. (1996) Relationship of genetic variation to population size in wildlife. Conservation Biology 10: 1500-1508.

Frankham, R. (2005) Genetics and extinction. Biological Conservation 126: 131-140.

Frick, A., Tanneberger, F. & Bellebaum, J. (2014) Model based selection of areas for the restoration of *Acrocephalus paludicola* habitats in NE Germany. Environmental Management 53: 728-738.

Gießing, B. (2002) Viele Väter für eine Brut – vorteilhaft oder unausweichlich für das Weibchen? [Many fathers of a brood – advantageous or inevitable for the female?] PhD thesis. 160 p. Cologne: University of Cologne.

GIOŚ (Główny Inspektorat Ochrony Środowiska, Chief Inspectorate of Environmental Protection) (2015) Państwowy Monitoring Środowiska, Monitoring wodniczki – instrukcja prac terenowych. [State Environmental Monitoring Scheme, Aquatic Warbler Monitoring Scheme – field methods] http://www.monitoringptakow.gios.gov.pl; consulted in 02/2018. (in Polish)

GIOŚ (Główny Inspektorat Ochrony Środowiska, Chief Inspectorate of Environmental Protection) (2017) Monitoring ptaków z uwzględnieniem obszarów specjalnej ochrony ptaków Natura 2000, lata 2015-2018. Etap V. [Bird monitoring scheme, including the SPA Natura 2000 sites, years 2015-2018. Stage V]. 223 p. Marki: GIOŚ. (in Polish)

Glapan, J. (2013) Zmienność geograficzna śpiewu wodniczki (*Acrocephalus paludicola*). [Geographical variation in the song of the Aquatic Warbler (*Acrocephalus paludicola*)] PhD thesis. 154 p. Poznań: Adam Mickiewicz University. (in Polish)

Gliźniewicz, M., Myślewski, M. & Głowacki, D. (2017) Analiza hydrotechniczna obszaru Bagien Rozwarowskich. [Hydrotechnical analysis of the Rozwarowo Marshes area] 98 p. Szczecin: Piotr Baliński projekt. (in Polish)

Goldammer, J.G., Montag, S. & Page, H. (1997) Nutzung des Feuers in mittel- und nordeuropäischen Landschaften – Geschichte, Methoden, Probleme, Perspektiven. [Use of fire in Central- and North-European landscapes – History, methods, problems, perspectives] NNA-Bericht 10: 18-38. (in German)

Gonin, J. & Mercier, F. (2014) Étude de la migration postnuptiale du Phragmite aquatique *Acrocephalus paludicola* en Baie de l'Aiguillon. Rapport de baguage 2013. [Study of the postnuptial migration of Aquatic Warbler *Acrocephalus paludicola* in Bay of Aiguillon. 2013 ringing report] La Rochelle: LPO Charente-Maritime. (in French)

Gonin, J. & Mercier, F. (2016) Etude de la migration postnuptiale du Phragmite aquatique *Acrocephalus paludicola* sur les RNN de la Baie de l'Aiguillon et de la Casse de la Belle Henriette. [Study on the postnuptial migration of the Aquatic Warbler *Acrocephalus paludicola* on the RNN at the Baie de l'Aiguillon and the Casse de la Belle Henriette] Unpublished report. 40 p. (in French)

Göttlich, K. & Kuntze, H. (1990) Moorkultivierung für Land- und Forstwirtschaft. [Peatland cultivation for agriculture and forestry] In: Moor- und Torfkunde [Peatland and peat science] (ed. by K. Göttlich), pp. 385-411. Stuttgart: Schweizerbart. (in German)

Grenouillet, G., Buisson, L., Casajus, N. & Lek, S. (2011) Ensemble modelling of species distribution: the effects of geographical and environmental ranges. Ecography 34: 9-17.

Grootjans, A., van Diggelen, R., Joosten, H. & Smolders, A.J.P. (2012) Restoration of mires. In: Restoration ecology: the new frontier (ed. by J. van Andel & J. Aronson), pp. 203-214. Oxford, UK: Wiley-Black-well.

Großkopf, J. (1988) Die Aktivitätsstruktur der Carabiden (Col.) des Straßenrandes als Folge von Mulchen und Saugmähen. [The activity patterns of roadside carabids as a result of mulching and suction mowing] Natur und Landschaft 63: 511-516. (in German)

Grueber, C.E., Wallis, G.P. & Jamieson, I.G. (2008) Heterozygosity – fitness correlations and their relevance to studies on inbreeding depression in threatened species. Molecular Ecology 17: 3978-3984.

Grummo, D.G. (ed.) (2015) Оценка степени трансформации, актуальных угроз и приоритетов в охране болотного масива «Дикое». [Evaluation of the state of transformation, current threats and priorities for conservation of Dzikoje wetland] Minsk. (in Russian)

Grummo, D.G. (2017) Оценка современного состояния и разработка прогноза динамики растительности модельных болот (Дикое, Дикий никор) национального парка «Беловежская пуща: отчет о НИР (заключ.) [Assessment of the current condition and elaboration of a prognosis of vegetation dynamics of model peatlands (Dzikoje, Dikiy Nikor) of the National Park 'Belavezhskaya Pushcha: report on scientific work (results).] 126 p. Minsk: Institut of Experimental Botany. (in Russian)
Grzywaczewski, G. (2015) Long-term changes in the population of the Aquatic Warbler *Acrocephalus paludicola* in Poleski National Park (eastern Poland) in the context of extensive agricultural use. Annales UMCS Sectio EE Zootechnica 33: 1-12.
Grzywaczewski, G. (2016) Wodniczka *Acrocephalus paludicola* – ornitologiczna perła Polesia zagrożona! [The Aquatic Warbler *Acrocephalus paludicola* - a jewel of the Polesie region is threatened!] Kwartalnik społeczno-kulturalny „Wschód" 21: 36-37. (in Polish)
Grzywaczewski, G. & Kitowski, I. (2018) Coal mining threatens the vulnerable Aquatic Warbler *Acrocephalus paludicola*. Oryx 52: 14.
Grzywaczewski, G., Cios, S., Sparks, T.H., Buczek, A. & Tryjanowski, P. (2014) Effect of habitat burning on the number of singing males of the Aquatic Warbler *Acrocephalus paludicola*. Acta Ornithologica 49: 175-182.
Grzywaczewski, G., Osiejuk, T., Cios, S. & Marczakiewicz, P. (2014) Song post selection in the Aquatic Warbler *Acrocephalus paludicola*. Annales Zoologici Fennici 51: 495-500.
Gunderson, L.H., (2000) Ecological resilience – in theory and application. Annual Review of Ecology and Systematics 31: 425-39.
Güsewell, S. & Le Nédic, C. (2004) Effects of winter mowing on vegetation succession in a lakeshore fen. Applied Vegetation Science 7: 41-48.
Güsewell, S., Le Nédic, C. & Buttler, A. (2000) Dynamics of Common Reed (*Phragmites australis* Trin.) in Swiss fens with different management. Wetlands Ecology and Management 8: 375-389.
Hald, A.B. & Vinther, E. (2000) Restoration of a species-rich fen-meadow after abandonment: response of 64 species to management. Applied Vegetation Science 3: 15-24.
Handke, K. (1988) Faunistisch-ökologische Untersuchungen auf Brachflächen in Baden-Württemberg. [Faunistic-ecological research on fallows in Baden-Wuerttemberg] Arbeitsberichte Lehrstuhl Landschaftsökologie Münster 8: 1-169. (in German)
Handke, K. (1997) Zur Wirbellosenfauna regelmäßig gebrannter Brachflächen in Baden-Württemberg 1983/84. [About the invertebrate fauna of periodic burned fallows in Baden-Wuerttemberg in 1983/84] NNA-Berichte 10: 72-81. (in German)
Handke, K. & Schreiber, K.-F. (1985) Faunistisch-ökologische Untersuchungen auf unterschiedlich gepflegten Parzellen einer Brachfläche im Taubergebiet. [Faunistic-ecologocal studies on differently managed plots of a fallow site in the Taubergebiet] Münstersche Geographische Arbeiten 20: 155-186. (in German)
Haslam, S.M. (1972) *Phragmites communis* Trin.: biological flora of the British Isles. Journal of Ecology 60: 585-610.
Hedberg, P., Saetre, P., Sundberg, S., Rydin, H. & Kotowski, W. (2013) A functional trait approach to fen restoration analysis. Applied Vegetation Science 16: 658-666.
Hedenström, A., Bensch, S., Hasselquist, D. & Ottosson, U. (1990) Observations of Palaearctic migrants rare to Ghana. Bulletin of the British Ornithologist's Club 110: 194-197.
Heise, G. (1963) Beiträge zur Brutbiologie und zum Verhalten des Seggenrohrsängers (*Acrocephalus paludicola*). [Contributions to breeding biology and behaviour of the Aquatic Warbler (*Acrocephalus paludicola*)] State examination thesis. Potsdam: Pädagogische Hochschule. (in German)
Heise, G. (1970a) Zur Brutbiologie des Seggenrohrsängers (*Acrocephalus paludicola*). [About the breeding biology of the Aquatic Warbler *Acrocephalus paludicola*] Journal of Ornithology 111: 54-67. (in German)
Heise, G. (1970b) Zum Brutvorkommen des Seggenrohrsängers, *Acrocephalus paludicola* (Vieillot), im Norden der DDR. [About the breeding occurrence of the Aquatic Warbler, *Acrocephalus paludicola* (Vieillot), in the North of the GDR] Beiträge zur Tierwelt der Mark 6: 77-87. (in German)
Heise, G. (1977) Seggenrohrsänger – *Acrocephalus paludicola* (Vieill. 1817). [Aquatic Warbler – *Acrocephalus paludicola*] In: Die Vogelwelt Mecklenburgs [The birdlife in Mecklenburg] (ed. by G. Klafs & J. Stübs), p. 232. Jena: Gustav Fischer Verlag. (in German)
Hemery, D., Blaize, C. & Jiguet, F. (2017) Les captures de Phragmites aquatiques en France, 2012. Plan national d'actions du phragmite aquatique 2013-2016. [Catches of Aquatic Warbler in France, 2012. National Aquatic Warbler Action Plan 2013-2016] 20 p. DREAL Bretagne – Bretagne Vivante-SEPNB. (in French)
Hemmann, K., Hopp, I. & Paulus, H.F. (1987) Zum Einfluss der Mahd durch Messerbalken, Mulcher und Saugmäher auf Insekten am Straßenrand. [About the influence of mowing by cutter bar, mulcher, and suction mower at the roadside] Natur und Landschaft 62: 103-106. (in German)
Heredia, B. (ed.) (1996) Action plan for the Aquatic Warbler *Acrocephalus paludicola* in Europe. 24 p. Cambridge: BirdLife International
Herold, B. (2013) Wasser, Wald und Wiesen – Artenschutz auf Landschaftsebene im EU-Life Projekt 'Schreiadler Schorfheide-Chorin'. [Water, forest, and meadows – species protection at landscape level in the EU-LIFE Project 'Lesser Spotted Eagle Schorfheide-Chorin'] Vogelwarte 51: 325-326. (in German)
Hesse, E. (1910) Beobachtungen und Aufzeichnungen während des Jahres 1909. [Observations and Recordings during the year 1909] Journal of Ornithology 58: 489-519. (in German)

Hesse, E. (1911) Beobachtungen und Aufzeichnungen während des Jahres 1910. [Observations and recordings during the year 1910] Journal of Ornithology 59: 361-383. (in German)

Hesse, E. (1912) Beobachtungen und Aufzeichnungen während des Jahres 1911. [Observations and recordings during the year 1911] Journal of Ornithology 60: 298-314. (in German)

Hesse, E. (1914) Die Vögel der Havelländischen Luchgebiete. [The birds of the Havelland Luch] Journal of Ornithology 62: 334-386. (in German)

Hodgson, J.G., Grime, J.P., Wilson, P.J., Thompson, K. & Band, S.R. (2005) The impacts of agricultural change (1963-2003) on the grassland flora of central England: processes and prospects. Basic and Applied Ecology 6: 107-118.

Hoffman, J.I., Simpson, F., David, P., Rijks, J.M., Kuiken, T., Thorne, M.A., Lacy, R.C. & Dasmahapatra, K.K. (2014) High-throughput sequencing reveals inbreeding depression in a natural population. PNAS 111: 3775-3780.

Holland, E.A., Dentener, F.J., Braswell, B.H., Sulzmann, J.M. (1999) Contemporary and pre-industrial global reactive nitrogen budgets. Biogeochemistry 46: 7-43.

Holsten, B., Neumann, H., Wiebe, C. & Wriedt, S. (2001) Die Wiedervernässung der Pohnsdorfer Stauung – eine Zwischenbilanz unter Berücksichtigung der Auswirkungen auf die Vegetation sowie die Amphibien- und Brutvogelbestände. [The rewetting of the Pohnsdorfer Stauung – interim results with regards to the effects on the vegetation as well as amphibians and breeding birds] Die Heimat 11: 195-205. (in German)

Holz, R., Sellin, D. &. Erdmann, F. (1983) Dynamik und Status der Avizönose des NSG "Peenetalmoor" – ein Beitrag zur Pflegekonzeption. [Dynamic and status of the bird community of the Nature Reserve 'Peenetalmoor' – a contribution to the management strategy] Archiv für Naturschutz und Landschaftsforschung 23: 223-249. (in German)

Hübner, E. (1908) Avifauna von Vorpommern und Rügen. [Avifauna of Western Pomerania and Rügen island] Leipzig: Theodor Oswald Weigel. (in German)

Humbert, J.-Y., Ghazoul, J., Richner, N. & Walter, T. (2010) Hay harvesting causes high orthopteran mortality. Agriculture, Ecosystems, and Environment 139: 522-527.

International Union for Conservation of Nature (IUCN) (2012) IUCN Red List Categories and Criteria: Version 3.1. Second edition. 32 p. Gland, Switzerland, and Cambridge, UK: IUCN.

Jabłońska, E., Michaelis, D., Tarapata, M., Goldstein, K., Grygoruk, M., Wilk, M., Wyszomirski, T. & Kotowski, W. (2018) Stability and resilience of mesotrophic rich fens – a plant functional ecology insight to palaeoecological data. Journal of Ecology. In revision.

Jakubas, D., Wojczulanis-Jakubas, K., Foucher, J., Dziarska-Palac, J. & Dugué, H. (2014) Age and sex differences in fuel load and biometrics of Aquatic warblers at autumn stopover site in the Loire Estuary (NW France). Ardeola 61: 15-30.

Jeganathan, P., Green, R.E., Norris, K., Vogiatzakis, I.N., Bartsch, A., Wotton, S.R., Bowden, C.G.R., Griffiths, G.H., Pain, D. & Rahmani, A.R. (2004) Modelling habitat selection and distribution of the critically endangered Jerdon's courser *Rhinoptilus bitorquatus* in scrub jungle: an application of a new tracking method. Journal of Applied Ecology 41: 224-237.

Jehle, P. & Pankoke, K. (1995) Vegetationskundliche Untersuchungen an Auenstandorten im Nationalpark Unteres Odertal. [Vegetation studies at floodplain sites in the National Park Unteres Odertal] Diploma thesis. Berlin: Technische Universität Berlin.

Jensen, K. & Gutekunst, K. (2003) Effects of litter on establishment of grassland plant species: the role of seed size and successional status. Basic and Applied Ecology 4: 579-587.

Jensen, K. & Meyer, C. (2001) Effects of light competition and litter on the performance of Viola palustris and on species composition and diversity of an abandoned fen meadow. Plant Ecology 155: 169-181.

Jensen, K. & Schrautzer, J. (1999) Consequences of abandonment for a regional fen flora and mechanisms of successional change. Applied Vegetation Science 2: 79-88.

Jiguet, F., Chiron, F., Dehorter, O., Dugué, H., Provost, P., Musseau, R., Guyot, G., Latraube, F., Fontanilles, P., Sechet, E., Laignel, J., Gruwier, X. & Le Nevé, A. (2011) How many Aquatic Warblers do stop in France during the autumn migration? Acta Ornithologica 46: 135-142.

Joosten, H. (2009) The global peatland CO_2 picture. Peatland status and emissions in all countries of the world. 35 p. Ede: Wetlands International.

Joosten, H. (2016a) Ecosystem services of peatlands. In: Paludiculture – productive use of wet peatlands. Climate protection – biodiversity – regional economic benefits (ed. by W. Wichtmann, C. Schröder & H. Joosten), pp. 15-18. Stuttgart: Schweizerbart Science Publishers.

Joosten, H. (2016b) Peatlands across the globe. In: Peatland restoration and ecosystem services: Science, policy and practice (ed. by A. Bonn, T. Allott, M. Evans, H. Joosten & R. Stoneman), pp. 19-43. Cambridge, Cambridge University Press.

Joosten, H. & Clarke, D. (2002) Wise use of mires and peatlands: Background and principles including a framework for decision-making. 304 p. Saarijärvi: International Mire Conservation Group and International Peat Society.

Joosten, H. & Couwenberg, J. (2009) Are emission reductions from peatlands MRV-able? 16 p. Ede: Wetlands International.

Joosten, H. & Tanneberger, F. (2017) Peatland use in Europe. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 151-172. Stuttgart: Schweizerbart Science Publishers

Joosten, H., Brust, K., Couwenberg, J., Gerner, A., Holsten, B., Permien, T., Schäfer, A., Tanneberger, F., Tepel, M. & Wahren, A. (2015) MoorFutures®. Integration of additional ecosystem services (including biodiversity) into carbon credits – standard, methodology and transferability to other regions. 120 p. Bonn: Bundesamt für Naturschutz.

Joosten, H., Gaudig, G., Tanneberger, F., Wichmann, S. & Wichtmann, W. (2016) Paludicultures: Sustainable productive use of wet and rewetted peatlands. In: Peatland restoration and ecosystem services: science, practice, policy. (ed. by A. Bonn, T. Allott, M. Evans, H. Joosten & R. Stoneman), pp. 339-357. Cambridge: Cambridge University Press.

Joosten, H., Moen, A., Couwenberg, J. & Tanneberger, F. (2017) Mire diversity in Europe: mire and peatland types. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger, & A. Moen), pp. 5-64. Stuttgart: Schweizerbart Science Publishers.

Jubete, F. (2001) La migración del Carricerín Cejudo en España y en la laguna palentina de La Nava. [The migration of the Aquatic Warbler in Spain and in the Palencia Lagoon of La Nava] Quercus 184: 18-23. (in Spanish)

Jubete, F., Torres, M., Gómez, E., Cirujano, S. & Zuazua, P. (eds) (2006) The Aquatic Warbler: manual for managing helophytic vegetation and monitoring populations. 144 p. Las Rozas, Madrid: Fundación Global Nature.

Julliard, R., Bargain, B., Dubos, A. & Jiguet, F. (2006) Identifying autumn migration routes for the globally threatened Aquatic Warbler *Acrocephalus paludicola*. Ibis 148: 735-743.

Jurzyk, S. (2004a) Znaczenie warunków siedliskowych w kształtowaniu struktury populacji woskownicy europejskiej *Myrica gale* L. i jej ochrona na Pomorzu Zachodnim. [The importance of site conditions for the population structure of Bog Myrtle *Myrica gale* L. and its protection in Western Pomerania] PhD thesis. Szczecin: Akademia Rolnicza. (in Polish)

Jurzyk, S. (2004b) Protection of *Myrica gale* L. brushwood in a peatbog under agricultural management. In: The future of Polish mires (ed. by L. Wołejko & J. Jasnowska), pp. 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 Journal of Ecology 51: 363-367.

Kamocki, A.K., Banaszuk, P. & Kołos, A. (2018) Removal of European alder *Alnus glutinosa* – an active method of mire conservation. Ecological Engineering 111: 44-50.

Kamocki, A.K., Kołos, A. & Banaszuk, P. (2016) Can we effectively stop the expansion of trees on wetlands? Result of a birch removal experiment. Wetlands Ecology and Management 25: 359-367.

Keller, L.F. & Waller, D.M. (2002) Inbreeding effects in wild populations. Trends in Ecology & Evolution 17: 230-241.

Kerbiriou, C., Bargain, B., Le Viol, I. & Pavoine, S. (2010) Diet and fuelling of the globally threatened Aquatic Warbler in autumn migration stopover as compared with two congeners. Animal Conservation 14: 261-270.

Kipper, S., Mundry, R., Sommer, C., Hultsch, H. & Todt, D. (2006) Song repertoire size is correlated with body measures and arrival date in Common Nightingales, *Luscinia megarhynchos*. Animal Behaviour 71: 211-217.

Kiryluk, H. & Borkowska-Niszczota, M. (2009) Evaluating attractiveness of Biebrza National Park tourist values as a result of questionnaire research. Economy and Management 1: 63-87. (in Polish with English summary)

Klimkowska, A. (2008) Restoration of severely degraded fens: ecological feasibility, opportunities and constraints. PhD thesis. 224 p. Antwerp: University of Antwerp.

Klimkowska, A., Kotowski, W., van Diggelen, R., Grootjans, A.P., Dzierza, P. & Brzezinska, K. (2010) Vegetation re-development after fen meadow restoration by topsoil-removal and hay transfer. Restoration Ecology 18: 924-933.

Klimkowska, A., van Diggelen, R., Bakker, J.P. & Grootjans, A.P. (2007) Wet meadow restoration in western Europe: a quantative assessment of the effectiveness of several techniques. Biological Conservation 140: 318-328.

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.

Klötzli, F. & Züst, S. (1973) Conservation of reed-beds in Switzerland. Polskie Archiwum Hydrobiologii 20: 229-235.

Knöfler, V. (2012) Habitat use of the Aquatic Warbler (*Acrocephalus paludicola*) in Lithuania 2011. Diploma thesis. 80 p. Greifswald: University of Greifswald.

Kohler, F., Gillet, F., Gobat, J.-M. & Buttler, A. (2004) Seasonal vegetation changes in mountain pastures due to simulated effects of cattle grazing. Journal of Vegetation Science 15: 143-150.

Koska, I. & Hacker, F. (2013) Wiederansiedlung typischer Pflanzengemeinschaften nährstoffarmer Basenreicher Niedermoore im renaturierten Quellmoor Kunsterwiese. Projekt 785 – Endbericht. [Recolonisation of typical plant societies of nutrient-poor, base-rich fens at the restored spring mire Kunsterwiese] 137 p. Greifswald: Institut für Landschaftsökologie und Naturschutz. (in German)

Koska, I. & Hacker, F. (2015) LIFE+-Projekt „Erhalt und Entwicklung kalkreicher Niedermoore („Braunmoosmoore", FFH-LRT 7230 in Brandenburg)": Teilprojekt "Wiederansiedlung typischer Pflanzengemeinschaften der Basen- und Kalk-Niedermoore" [LIFE+ project 'Protection and development of base-rich and calcareous fens ('Brownmoss mires'). Subproject 'Recolonisation of typical plant communities of nutrient-poor, base-rich fens']. Greifswald: Institut für Landschaftsökologie und Naturschutz. (in German)

Koska, I., Succow, M., Clausnitzer, U., Timmermann, T. & Roth, S. (2001) Vegetationskundliche Kennzeichnung von Mooren (topische Betrachtung). [Vegetation-based classification of mires] In: Landschaftsökologische Moorkunde, 2. Ausgabe [Landscape ecology of mires, 2nd ed.] (ed. by M. Succow & H. Joosten), pp. 112-184. Stuttgart: Schweizerbart Science Publishers. (in German)

Kotowski, W. (2002) Fen communities. Ecological mechanisms and conservation strategies. PhD thesis. Groningen: University of Groningen.

Kotowski, W., Dembek, W. & Pawlikowski, P. (2017) Poland. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 549-571. Stuttgart: Schweizerbart Science Publishers.

Kotowski, W., Jabłońska, E. & Bartoszuk, H. (2013) Conservation management in fens: do large tracked mowers impact functional plant diversity? Biological Conservation 167: 292-297.

Kotowski, W., van Andel, J., van Diggelen, R. & Hogendorf, J. (2001) Responses of fen plant species to groundwater level and light intensity. Plant Ecology 155: 147-156.

Kovács, G. & Végvári, Z. (1999) Population size and habitat of the Aquatic Warbler *Acrocephalus paludicola* in Hungary. Vogelwelt 120: 121-126.

Kozlovskyi, B.I. (2005) Меліоративний стан осушуваних земель західних областей України. [Reclamation state of drained lands of western regions of Ukraine]. 420 p. Lviv: Evrosvit. (in Ukrainian)

Kozulin, A. (2011) Rewetting of peatland. In: Carbon credits from peatland rewetting. Climate – biodiversity – land use. Science, policy, implementation and recommendations of a pilot project in Belarus. (ed. by F. Tanneberger & W. Wichtmann), pp. 9-12. Stuttgart: Schweizerbart Science Publishers.

Kozulin, A. & Flade, M. (1999) Breeding habitat, abundance and conservation status of the Aquatic Warbler *Acrocephalus paludicola* in Belarus. Vogelwelt 120: 97-112.

Kozulin, A.V. & Tanovitskaya, N.I. (2017) Правила эксплуатации водорегулирующих сооружений для оптимизации гидрологического режима республиканского ландшафтного заказника Званец. [Rules for the operation of water regulating structures to optimise the hydrological regime of the Zvaniec national landscape reserve] Prepared in the frame work of a EU/UNDP ClimaEast project. 27 p. Minsk. (in Russian)

Kozulin, A. & Vergeichik, L. (2006) Dynamics of the Aquatic Warbler (*Acrocephalus paludicola*) population at the Zvanets mire (Belarus). Acta Zoologica Lituanica 16: 261-270.

Kozulin, A.V., Flade, M. & Gritschik, W.W. (1999) Fen mires and benefit of mobility: a hypothesis for the origin of promiscuity in Aquatic Warbler (*Acrocephalus paludicola*). Subbuteo 2: 11-17.

Kozulin, A.V., Tanovitskaya, N.I. & Bambalov, N.N. (2017) Болота Беларуси [Mires of Belarus] 105 p. Minsk. (in Russian)

Kozulin, A.V., Tanovitskaya, N.I., Navosha, Y.Y., Il'yuchik, M.A. & Ratnikova, O.N. (2012) Инвентаризация естественных болот Беларуси с использованием методов космического зондирования [Inventarisation of natural peatlands in Belarus using remote sensing methods] Prirodnye resursy 1: 46-53. (in Russian)

Kozulin, A., Tanovitskaya, N. & Vershitskaya, I. (2010) Methodological recommendations for ecological rehabilitation of damaged mires and prevention of disturbances to the hydrological regime of mire ecosystems in the process of drainage. Scientific and Practical Center for Bio Resources. Institute for Nature Management of the National Academy of Sciences of Belarus. 39 p. Minsk: UNDP.

Kozulin, A., Vergeichik, L. & Stepanovich, Y. (2004) Factors affecting fluctuations of the Aquatic Warbler *Acrocephalus paludicola* population of Byelarussian mires. Acta Ornithologica 39: 35-44.

Kratz, R. & Pfadenhauer, J. (eds) (2001) Ökosystemmanagement für Niedermoore – Strategien und Verfahren zur Renaturierung [Ecosystem management for fens: strategies and procedures for restoration], 317 p. Stuttgart: Ulmer. (in German)

Kraus, R.H., von Holdt, B., Cocchiararo, B., Harms, V., Bayerl, H., Kühn, R., Förster, D.W., Fickel, J., Roos, C. & Nowak, C. (2015) A single-nucleotide polymorphism-based approach for rapid and cost-effective genetic wolf monitoring in Europe based on noninvasively collected samples. Molecular Ecology Re-sources 15: 295-305.

Kraus, R.H.S. & Wink, M. (2015) Avian genomics: fledging into the wild! Journal of Ornithology 156: 851-865.

Krisch, H., Krauss, N. & Kahl, M. (1979) Der Einfluss von Schnitt und Frost auf Entwicklung und Biomassproduktion der *Phragmites*-Röhrichte am Greifswalder Bodden. [The influence of cutting and frost on the development and biomass production of *Phragmites* reedbeds at the Greifswalder Bodden] Folia Geobotanica Phytotaxonomica 14: 121-144. (in German)

Krogulec, J. & Kloskowski, J. (2003) Monitoring Aquatic Warbler *Acrocephalus paludicola* in Poland. Ornis Hungarica 12: 191-196.

Krogulec, J. & Wołczuk, B. (2014) Analiza możliwości połączenia wschodniej i zachodniej populacji wodniczki *Acrocephalus paludicola* w Polsce poprzez odtworzenie zdegradowanych siedlisk wodniczki na obszarze rozgraniczającym te populacje. Etap I. [Feasibility study on linking the eastern and western population of the Aquatic Warbler Acrocephalus paludicola in Poland by restoring degraded habitats at the margins of these populations] 28 p. Warsaw: OTOP. (in Polish)

Kubacka, J., Oppel, S., Dyrcz, A., Lachmann, L., Costa, P., Kail, U. & Zdunek, W. (2014) Effect of mowing on productivity in the endangered Aquatic Warbler *Acrocephalus paludicola*. Bird Conservation International 24: 45-58.

Lachmann, L. & Zadrąg, M. (2011) Polish National Species Action Plan for the Aquatic Warbler *Acrocephalus paludicola*. Prepared by OTOP on behalf of the General Directorate for Environment Protection, Poland. 111 p. Unpublished.

Lachmann, L., Marczakiewicz, P. & Grzywaczewski, G. (2010) Protecting Aquatic Warblers (*Acrocephalus paludicola*) through a landscape-scale solution for the management of fen peat meadows in Poland. Grassland Science in Europe 15: 711-713.

Laikre, L. (2010) Genetic diversity is overlooked in international conservation policy implementation. Conservation Genetics 11: 349-354.

Laiolo, P. (2010) The emerging significance of bioacoustics in animal species conservation. Biological Conservation 143: 1635-1645.

Laiolo, P. & Tella, J.L. (2007) Erosion of animal cultures in fragmented landscapes. Frontiers in Ecology and the Environment 5: 68-72.

Latraube, F. & Le Nevé, A. (2014) La migration postnuptiale du Phragmite aquatique en région Pays de la Loire et les habitats fréquentés. [Post-nuptial migration of Aquatic Warbler to Pays de la Loire region and habitat use] Alauda 82: 291-305. (in French)

Latraube, F. (2013) Bilan de la prospection Phragmite aquatique *Acrocephalus paludicola* réalisée sur les marais de Mazerolles du 5 au 13 août 2013. [Review of the Aquatic Warbler *Acrocephalus paludicola* survey carried out on the marshes of Mazerolles from 5 to 13 August 2013.] 8 p. Ligue pour la protection des oiseaux en Loire-Atlantique. (in French)

Le Nevé, A. & Bargain, B. (2009) Recueil d'expériences: écologie et gestion des habitats du Phragmite aquatique en halte migratoire. Life-Nature 'Conservation du Phragmite aquatique en Bretagne' 2004-2009. [Collection of experiments: ecology and habitat management of Aquatic Warbler in stopover. Life-Nature 'Conservation of Aquatic Warbler in Brittany' 2004-2009] 104 p. Brest: Bretagne Vivante-SEPNB. (in French)

Le Nevé, A., Bargain, B., Provost, P. & Latraube, F. (2009) Le phragmite aquatique *Acrocephalus paludicola*. Plan national d'actions 2010-2014. [The Aquatic Warbler *Acrocephalus paludicola*. National Action Plan 2010-2014] 177 p. Nantes, Brest: DREAL Bretagne, Bretagne Vivante-SEPNB. (in French)

Le Nevé, A., Bussière, R., Jacob, Y. & Rguibi, H. (2013a) Recherche de la migration postnuptiale de l'espèce au Maroc en août 2012. Plan national d'actions du Phragmite aquatique 2010-2014. [Research of the post-nuptial migration of the species in Morocco in August 2012. National Aquatic Warbler Action Plan 2010-2014.] 50 p. Nantes, Brest: DREAL Bretagne, Bretagne Vivante-SEPNB. (in French)

Le Nevé, A., Dehorter, O., Dugué, H., Latraube, F., Musseau, R., Provost, P. & Jiguet, F. (2013b) Synthèse des captures de phragmites aquatiques en France en 2010 et 2011. Plan national d'actions du phragmite aquatique 2010-2014. [Summary of Aquatic Warbler catches in France in 2010 and 2011. National Aquatic Warbler Action Plan 2010-2014] 57 p. Nantes: DREAL Bretagne. (in French)

Le Nevé, A., Dehorter, O., Lorrillière, R. & Fiquet, P. (2013c) Recherche de la migration prénuptiale de l'espèce sur le littoral méditerranéen français en avril 2012. Plan national d'actions du Phragmite aquatique 2010-2014. [Research of the prenuptial migration of the species on the French Mediterranean coast in April 2012. National Aquatic Warbler Action Plan 2010-2014] 64 p. Nantes, Brest: DREAL Bretagne, Bretagne Vivante-SEPNB. (in French)

Le Nevé, A., Latraube, F., Provost, P. & Jiguet, F. (2011) Synthèse des captures de phragmites aquatiques en France en 2008 et 2009. Plan national d'actions du phragmite aquatique 2010-2014. [Summary of Aquatic Warbler catches in France in 2008 and 2009. National Aquatic Warbler Action Plan 2010-2014] 52 p. Nantes: DREAL Bretagne. (in French)

League for the Protection of Birds (LPO) (2017) http://www.ornitho.fr; consulted in 11/2017.

Leisler, B. (1975) Die Bedeutung der Fußmorphologie für die ökologische Sonderung mitteleuropäischer Rohrsänger (*Acrocephalus*) und Schwirle (*Locustella*). [The relevance of tarsus morphology of central European Warblers (*Acrocephalus*, *Locustella*) for their ecological separation] Journal of Ornithology 116: 117-153. (in German)

Leisler, B. (1981) Die ökologische Einnischung der mitteleuropäischen Rohrsänger (*Acrocephalus*, Sylviinae). I. Habitattrennung. [Ecological niche partitioning of central European Warblers (*Acrocephalus*, Sylviinae). I. Habitat separation] Die Vogelwarte 31: 45-74. (in German)

Leisler, B. (1988) Intra- und interspezifische Aggression bei Schilf- und Seggenrohrsänger (*Acrocephalus schoenobaenus*, *A. paludicola*): Ein Fall yon akustischer Verwechslung? [Intra- and interspecific aggression in Sedge and Aquatic Warbler (*Acrocephalus schoenobaenus*, *A. paludicola*): a case of acoustic mix-up?] Vogelwarte 34: 281-290. (in German)

Leisler, B. (1991) Mariskensänger (*Acrocephalus melanopogon*). [Moustached Warbler (*Acrocephalus melanopogon*)] In: Handbuch der Vögel Mitteleuropas [Handbook of the birds of central Europe] (ed. by U.N. Glutz von Blotzheim), pp. 217-251. Wiesbaden: Aula. (in German)

Leisler, B. & Catchpole, C.K. (1992) The evolution of polygamy in European reed warblers of the genus *Acrocephalus*: a comparative approach. Ethology, Ecology and Evolution 4: 225-243.

Leisler, B. & Schulze-Hagen, K. (2011) The Reed Warblers: Diversity in a uniform bird family. 320 p. Zeist, The Netherlands: KNNV Publishing.
Leisler, B., Ley, H.W. & Winkler, H. (1989) Habitat, behaviour and morphology of *Acrocephalus* warblers: an integrated analysis. Ornis Scandinavica 20: 181-186.
Leisler, B., Winkler, H. & Wink, M. (2002) Evolution of breeding systems in acrocephaline warblers. The Auk 119: 379-390.
Leitner, S. & Catchpole, C.K. (2004) Syllable repertoire and the size of the song control system in captive Canaries (*Serinus canaria*). Journal of Neurobiology 60: 21-27.
Leyer, I. (2002) Auengrünland der Mittelelbe-Niederung. Vegetationskundliche und -ökologische Untersuchungen in der rezenten Aue, der Altaue und am Auenrand der Elbe. [Floodplain grassland in the Middle Elbe lowland. Studies of vegetation science and ecology in the recent floodplain, the former floodplain and along the floodplain margin oft he Elbe] Dissertationes Botanicae 363. 193 p. Berlin, Stuttgart: J. Cramer. (in German)
Liukart, G., Ryman, N., Tallmon, D.A., Schwatz, M.K. & Allendorf, F.W. (2010) Estimation of census and effective population sizes: the increasing usefulness of DNA-based approaches. Conservation Genetics 11: 355-373.
Malashevich, U. (2010) Report on estimation of the Aquatic Warbler population in Belarus, 2010. 20 p. Minsk: APB – BirdLife Belarus.
Malashevich, U. (2013) Report on estimation of the Aquatic Warbler population in Belarus, 2013. 17 p. Minsk: APB – BirdLife Belarus.
Malashevich, U. (2016) Отчет о мониторинге численности и распределения вертлявой камышевки на болоте Дикое и Сервечь, Беларусь, 2016. [Monitoring report on the number and distribution of the Aquatic Warbler at Dzikoje and Servech, Belarus, 2016] Minsk: APB. 10 p. (in Russian)
Marczakiewicz, P. &, Grzywaczewski, G. (2008) Research on Aquatic Warbler at Biebrza Valley. In: The Aquatic Warbler, a global threatened species. Proceedings of the LIFE seminar 'Conservation of the Aquatic Warbler in Brittany', pp. 34-39.
Marquet, M., Bonnet, P., Séchet, E., Robin, J., Bécheau, F. & Kerbiriou, C. (2014) La Brière, un site de halte migratoire d'importance pour le Phragmite aquatique *Acrocephalus paludicola* et éléments d'écologie de l'espèce sur ce site. [La Brière, a migratory stopover site of importance for the Aquatic Warbler *Acrocephalus paludicola* and ecology of the species on this site] Alauda 82: 249-268. (in French)
Marschalek, H., Neugebauer, K. & Sturm, P. (2006) Schilffrühmahd als Pflegemaßnahme zur Wiederherstellung verbrachter Streuwiesen. [Early mowing as a means to control the Common Reed (*Phragmites australis*) in order to conserve typical fen meadows] Unpublished report. 31 p. (in German)
Matus, G., Verhagen, R., Bekker, R.M., Grootjans, A.P. & Bruelheide, H. (eds) (2003) Restoration of the Cirsio dissecti-Molinietum in The Netherlands: Can we rely on soil seed banks? Applied Vegetation Science 6: 73-84.
Matuszkiewicz, A.J., Głowacka, I., Jakubowski, W., Kamiński, J., Myśliński, G. & Sobczyński, L. (1999) Plan Ochrony BPN. Operat ochrony lądowych ekosystemów nieleśnych. [Protection Plan for the Biebrza National Park. A survey of protection of non-forest land ecosystems] Biebrza National Park. (in Polish)
Maumary, L., Vallotton, L. & Knaus, P. (2007) Les oiseaux de Suisse. [The birds of Switzerland] 848 p. Sempach, Montmollin: Station ornithologique suisse, Sempach, Nos Oiseaux. (in French)
Mayfield, H. (1975) Suggestions for calculating nest success. The Wilson Bulletin 87: 456-466.
McBride, A., Diack, I., Droy, N., Hamill, B., Jones, P., Schutten, J., Skinner, A. & Street, M. (eds) (2010) The fen management handbook. 329 p. Perth: Scottish Natural Heritage.
McCarthy, D.P., Donald, P.F., Scharlemann, J.P., Buchanan, G.M., Balmford, A., Green, J.M., Bennun, L.A., Burgess, N.D., Fishpool, L.D., Garnett, S.T., Leonard, D.L., Maloney, R.F., Morling, P., Schaefer, H.M., Symes, A., Wiedenfeld, D.A. & Butchart, S.H. (2012) Financial costs of meeting global biodiversity conservation targets: current spending and unmet needs. Science 338: 946-949.
Michaelis, D. (2002) Die spät- und nacheiszeitliche Entwicklung der natürlichen Vegetation von Durchströmungsmooren in Mecklenburg-Vorpommern am Beispiel der Recknitz. [The late- and postglacial development of the natural vegetation of the percolation mires of Mecklenburg-West Pomerania, using the example of the Recknitz valley] Dissertationes Botanicae 365: 1-188. (in German)
Michaelis, D. & Joosten, H. (2007) Mire development, relative sealevel change, and tectonic movement along the Northeast-German Baltic Sea coast. Berichte der Römisch-Germanischen Kommission 88: 149-182.
Middleton, B.A. (2002) Winter burning and the reduction of *Cornus sericea* in sedge meadows in southern Wisconsin. Restoration Ecology 10: 723-730.
Miguélez, D., García, J., Zumalacárregui, C. & Fuertes, B. (2014) Does the Aquatic Warbler *Acrocephalus paludicola* show differential migration by age during the autumn in the Iberian Peninsula? Journal of Ornithology 155: 829-833.
Miguélez, D., García-Tejero, S., Hernández, Á. & Valladares, L.F. (2016) Diet selection of the Aquatic Warbler *Acrocephalus paludicola* during its post-nuptial migration stopover in NW Spain. Ardea 104: 273-282.
Miguélez, D., Zumalacárregui, C., Fuertes, B., Astiárraga, H., González-Jáñez, R., Roa, I. & de la Calzada, F. (2009) Habitat, phenology and biometrics of the Aquatic Warbler *Acrocephalus paludicola* during autumn migration through a riverine wetland in Iberia. Ringing & Migration 24: 277-279.

Moen, A., Joosten, H. & Tanneberger, F. (2017) Mire diversity in Europe: mire regionality. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger, & A. Moen), pp. 97-147. Stuttgart: Schweizerbart Science Publishers.

Movchan, I., Parchuk, H. & Vakarenko, L. (2017) Ukraine. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 691-704. Stuttgart: Schweizerbart Science Publishers.

Musseau, R. & Herrmann, V. (2013) Gironde estuary, France: important autumn stopover site for Aquatic Warbler. Dutch Birding 35: 15-23.

Musseau, R., Boutault, L. & Beslic, S. (2018) Rapid losses of intertidal salt marshes due to global changes in the Gironde estuary (France) and conservation implications for marshland passerines. Journal of Coastal Conservation January 2018: 1-9.

Musseau, R, Herrmann, V., Bénard, S., Kerbiriou, C., Herault, T. & Jiguet, F. (2014) Ecology of Aquatic Warblers *Acrocephalus paludicola* in a fall stopover area on the Atlantic coast of France. Acta Ornithologica 49: 93-105.

Musseau, R., Herrmann, V., Kerbiriou, C., Bénard, S., Herault, T., Kerbiriou, E. & Jiguet, F. (2014) Ecology of Aquatic Warblers *Acrocephalus paludicola* in a fall stopover area on the atlantic coast of France. Acta Ornithologica 49: 93-105.

Nawrocki, P., Jermaczek, A., Jesionowski, J., Nawrocka, B. & Winiecki, A. (1982) Ptaki Bagien Kramskich w okresie lęgowym w latach 1976-1979. [Birds of the Kramsk peatlands during breeding period in the years 1976-1979] Poznańskie Towarzystwo Przyjaciół Nauk, Prace Komisji Biologicznej 67: 19-41. (in Polish)

Neto, J., Encarnação, V. & Fearon, P. (2010) Distribution, phenology and condition of Aquatic Warblers *Acrocephalus paludicola* migrating through Portugal. Ardeola 57: 181-189.

Newton, I. (1998) Population limitation in birds. 597 p. London: Academic Press.

Nikiforov, M.E., Bambalov, N.N., Kozulin, A.V., Tanovitskaya, N.A. & Rakovich, V.A. (2013) Аналитический доклад Реабилитация и устойчивое управление торфяниками для обеспечения экологической безопасности и сохранения биологического разнообразия. [Analytical presentation on rehabilitation and sustainable use of peatlands for securing ecological safety and protection of biological diversity] Unpublished.

Nowicki, S. & Searcy, W.A. (2004) Song function and the evolution of female preferences: Why birds sing and why brains matter. Annales of the New York Academy of Sciences 1016: 704-723.

Nowysz, W. & Wesołowski, T. (1972) Ptaki Kostrzyńskiego Zbiornika Retencyjnego i okolic w sezonie lęgowym. [Birds of the Kostrzyn retention basin and surroundings during breeding season] Notatki Przyrodnicze 6: 3-31. (in Polish)

O'Grady, J.J., Brook, B.W., Reed, D.H., Ballou, J.D., Tonkyn, D.W. & Frankham, R. (2006) Realistic levels of inbreeding depression strongly affect extinction risk in wild populations. Biological Conservation 133: 42-51.

O'Sullivan, R. & Emmer, I. (2011) Selling peatland rewetting on the voluntary carbon market. In: Carbon credits from peatland rewetting. Climate – biodiversity – land use. Science, policy, implementation and recommendations of a pilot project in Belarus (ed. by W. Wichtmann & F. Tanneberger), pp. 94-99. Stuttgart: Schweizerbart Science Publishers.

Øien, D.-I. & Moen, A. (2001) Nutrient limitation in boreal plant communities and species influenced by scything. Applied Vegetation Science 4: 197-206.

Olde Venterink, H., Kardel, I., Kotowski, W., Peeters, W. & Wassen, M.J. (2009) Long-term effects of drainage and hay-removal on nutrient dynamics and limitation in the Biebrza mires, Poland. Biogeochemistry 93: 235-252.

Oppel, S., Marczakiewicz, P. & Lachmann, L. (2013) The development of Aquatic Warbler numbers and distribution in Bagno Ławki /Biebrza NP in relation to management measures. Analysis of full count data 2005-2010. In: Final monitoring report on the LIFE05 NAT/PL/000101 project 'Conservation of *Acrocephalus paludicola* in Poland and Germany'. (ed. by OTOP, the Polish Society for the Protection of Birds), pp. 272-283. Marki.

Oppel, S., Pain, D.J., Lindsell, J.A., Lachmann, L., Diop, I., Tegetmeyer, C., Donald, P.F., Anderson, G., Bowden, C.G.R., Tanneberger, F. & Flade, M. (2011) High variation reduces the value of feather stable isotope ratios in identifying new wintering areas for aquatic warblers *Acrocephalus paludicola* in West Africa. Journal of Avian Biology 42: 342-354.

Oppermann, R. & Claßen, A. (1998) Naturverträgliche Mähtechnik – Moderne Mähgeräte im Vergleich. [Nature-compatible mowing techniques – modern mowers in comparison] Grüne Reihe. 48 p. Stuttgart: NABU e.V. Landesverband Baden-Württemberg. (in German)

Oppermann, R. & Krismann, A. (2002) Naturverträgliche Mähtechnik und Populationssicherung. [Nature-compatible mowing techniques and population protection] BfN-Skripten 54. 76 p. Bonn: Bundesamt für Naturschutz. (in German)

Osbourne, P.E., Alonso, J.C. & Bryant, R.G. (2001) Modeling landscape-scale habitat use using GIS and remote sensing: a case study with great bustards. Journal of Applied Ecology 38: 458-471.

Ostendorp, W. (1999) Management impacts on stand structure of lakeshore *Phragmites* Reed. International Review of Hydrobiology 84: 33-47.

OTOP (Polish Society for the Protection of Birds) (2013) Final monitoring report on the LIFE05 NAT/PL/000101 project 'Conservation of the Aquatic Warbler in Poland and Germany'. Marki: OTOP. 308 p.

OTOP (Polish Society for the Protection of Birds) (2014) Raport monitoringów w projekcie LIFE+ „Wodniczka i biomasa" (lata 2011-2014) wraz z oceną działań projektu [A monitoring report on the LIFE+ project 'Aquatic Warbler and biomass' (2011-2014) and evaluation of project actions]. Marki: OTOP. (in Polish)

Owens, I.P.F. & Bennett, P.M. (2000) Ecological basis of extinction risk in birds: Habitat loss versus human persecution and introduced predators. PNAS 97: 12144-12148.

Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.-D.V., Jayak, A. & Limink, S. (2002) The amount of carbon released from peat and forest fires in Indonesia during 1997. Nature 420: 61-65.

Pain, D.J., Green, R.E., Giessing, B., Kozulin, A., Poluda, A., Ottosson, U., Flade, M. & Hilton, G.M. (2004) Using stable isotopes to investigate migratory connectivity of the globally threatened Aquatic Warbler *Acrocephalus paludicola*. Oecologia 138: 168-174.

Pakalne, M. & Aleksāns, O. (2017) Latvia. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 478-485. Stuttgart: Schweizerbart Science Publishers.

Pałczyński, A. (1985) Succession trends in plant communities of the Biebrza valley. Polish Ecological Studies 11: 5-20.

Patzelt, A., Wild, U. & Pfadenhauer, J. (2001) Restoration of wet fen meadows by topsoil removal: vegetation development and germination biology of fen species. Restoration Ecology 9: 127-136.

Payevskiy, V.A. (1985) Демография птиц. [Avian demography] 285 p. Leningrad: Nauka. (in Russian)

Payevsky, V.A., Vysotsky, V.G., Yefremov, V.D., Markovets, M.Y., Morozov, Y.G. & Shapoval, A.P. (1997) Sex-specific survival rates in birds. Journal of General Biology 58: 5-20.

Peach, W.J., Baillie, S. & Underhill, L. (1991) Survival of British Sedge Warblers *Acrocephalus schoenobaenus* in relation to west African rainfall. Ibis 133: 300-305.

Peach, W.J., Buckland, S.T. & Baillie, S.R. (1990) Estimating survival rates using mark–recapture data from multiple ringing sites. The Ring 13: 87-102.

Pfadenhauer, J., Höper, H., Borkowsky, O., Roth, S., Seeger, T. & Wagner, C. (2001) Entwicklung pflanzenartenreichen Niedermoorgrünlands. [Development of plant-rich fen grassland] In: Ökosystemmanagement für Niedermoore: Strategien und Verfahren zur Renaturierung [Ecosystem management for fens: strategies and procedures for restoration] (ed. by R. Kratz & J. Pfadenhauer), pp. 134-153. Stuttgart: Ulmer. (in German)

Pitkänen, A., Turunen, J. & Tolonen, K. (1999) The role of fire in the carbon dynamics of a mire, eastern Finland. Holocene 9: 453-462.

Poluda, A. (2008) Hydraulic management of Aquatic Warbler habitats in the upper Pripyat river region (Ukraine). In: The Aquatic Warbler, a global threatened species. Proceeding of the Life seminar 'Conservation of the Aquatic Warbler in Brittany'. Penn ar Bed 206, pp. 61-67. Quimper: Bretagne Vivante-SEPNB.

Poluda, A.M. (2009) Гнездовые группировки вертлявой камышевки в Украине и их природоохранный статус. [Breeding sites of the Aquatic Warbler in Ukraine and their conservation status]. Berkut 18: 143-163. (in Russian)

Poluda, A. (2015) National report from Ukraine, UNEP/CMS/AW-3/Doc.6.2. Convention on Migratory Species meeting in 2015. 19 p.

Poluda, A. (2017) Monitoring of Aquatic Warbler breeding groups in Ukraine in 2017. Project report. 37 p. Kyiv: Ukrainian Society for the Protection of Birds.

Poluda, A., Flade, M., Foucher, J., Kiljan, G., Tegetmeyer, C. & Salewski, V. (2012): First confirmed connectivity between breeding sites and wintering areas of the globally threatened Aquatic Warbler *Acrocephalus paludicola*. Ringing & Migration 27: 57-59.

Poluda, A., Flade, M., Krogulec, J., Khymyn, M., Iliukha, O. & Korkh Y. (2016) Monitoring of Aquatic Warbler *Acrocephalus paludicola* (Vieillot, 1817) in Ukraine in 2016. Scientific Bulletin of the National Park 'Prypiat-Stokhid' 6: 1-29.

Poluda, A., Leheida, I., Priadko, O., Osadcha, O. & Lukianchuk, Z. (2007) Менеджмент-план для територій, які є місцями гніздування птахів деснянсько-дніпровського популяційного угруповання прудкої очеретянки. [Management plan for breeding territories of Aquatic Warbler of Desna-Dnipro population]. 80 p. Kiev: Ukrainian Society for the Protection of Birds. (in Ukrainian)

Poulin, B., Duborper, E. & Lefebvre, G. (2010) Spring stopover of the globally threatened Aquatic Warbler *Acrocephalus paludicola* in Mediterranean France. Ardeola 51: 167-173.

Povilaitis, R., Taminskas, J., Gulbinas, Z., Linkevičienė, R. & Pileckas, M. (2011) Lietuvos šlapynės ir jų vandensauginė reikšmė. [Lithuanian wetlands and their water protective importance] 327 p. Vilnius: Gamtos paveldo fondas. (in Lithuanian)

Prochnow, A. & Kraschinski, S. (2001) Angepasstes Befahren von Niedermoorgrünland. Merkblatt 323. [Adjusted driving on fen grassland] 16 p. Frankfurt/Main: Deutsche Landwirtschaftsgesellschaft. (in German)

Provost, P., Kerbiriou, C. & Jiguet, F. (2010) Foraging range and habitat use by Aquatic Warblers *Acrocephalus paludicola* during a fall migration stopover. Acta Ornithologica 45: 173-180.

Purvis, A., Gittleman, J.L., Cowlishaw, G. & Mace, G.M. (2000) Predicting extinction risk in declining species. Proceedings of the Royal Society B 267: 1947-1952.

Ramotowska, K. (2006) Trendy rozwojowe turystyki i związane z nimi oczekiwania wobec Parku. Materiały z konferencji 'Biebrzański Park Narodowy w zrównoważonym rozwoju' [Development trends in tourism and related expectations towards the Park. Materials from the conference 'Biebrza National Park in Sustainable Development'], pp. 54-55. Osowiec-Twierdza: Biebrza National Park. (in Polish)

Ramseier, D. (2000) Why remove the topsoil for fen restoration? – Influence of water table, nutrients and competitors on the establishment of four selected plant species. Bulletin of the Geobotanical Institute ETH Zürich 66: 25-35.

Rechberger, C. (2003): Schilf (*Phragmites australis*): Analyse der Ernte- und Verwertungsmöglichkeiten unter besonderer Berücksichtigung des Neusiedler Sees. [Common Reed (*Phragmites australis*): Analysis of possibilities for harvest and its use in regard to the Lake Neusiedl] Diploma thesis. 131 p. Vienna: Highschool of Wiener Neustadt. (in German)

Reise, K. (1998) Deichvorland und Salzwiesen. [Embankment foreland and salt marshes] In: Naturschutz in der Kulturlandschaft. Schutz und Pflege von Lebensräumen [Nature protection in the cultural landscape. Protection and maintenance of habitats] (ed. by. U. Wegener), pp. 116-120. Heidelberg: Spektrum Akademischer Verlag. (in German)

Rennwald, E. (2000) Verzeichnis und Rote Liste der Pflanzengesellschaften Deutschlands. Schriftenreihe für Vegetationskunde 35. [Directory and Red List of plant communities in Germany] 800 p. Bonn-Bad Godesberg: Bundesamt für Naturschutz. (in German)

Rguibi Idrissi, H. (2002) Analyse comparative de la migration et l'hivernage de quelques passereaux au Maroc à partir des données de baguage et le suivi quotidien dans deux zones humides marocaines. [Comparative analysis of the migration and wintering of some passerines in Morocco from ringing data and daily monitoring in two Moroccan wetlands] PhD thesis. 176 p. Oldenburg: University of Oldenburg. (in French)

Rguibi Idrissi, H., Dakki, M. & Bairlein, F. (2007) Migration et hivernage de quelques passereaux au Maroc: mise au point à partir des données de baguage-reprise. [Migration and wintering of some passerines in Morocco: development from ringing-recovery data] Ostrich 78: 343-347. (in French)

Ritterbusch, D., Lewin, C. & Ristow, M. (2017) Auswirkungen einer winterlichen Rohrwerbung auf Bestandsstruktur und Habitatfunktion von *Phragmites*-Röhrichten. [Impacts of winterly reed-cutting on stock structure and habitat function of *Phragmites* reedbeds] Schriften des Instituts für Binnenfischerei e.V. Potsdam-Sacrow 45: 1-118. (in German)

Roberge, J.-M. & Angelstam, P. (2004) Usefulness of the umbrella species concept as a conservation tool. Conservation Biology 18: 76-85.

Robien, P. (1920) Die Vogelwelt des Bezirks Stettin. Teil 1. [The birdlife of the Szczecin district. Part 1] 112 p. Szczecin: L. Saunier. (in German)

Robles, M. & Arcas, J. (2004) Datos sobre la fenología y condición corporal del carricerín cejudo (*Acrocephalus paludicola*) durante la migración otoñal en Galicia (noroeste de España). [Data on the phenology and body condition of the Aquatic Warbler (*Acrocephalus paludicola*) during the autumn migration in Galicia (northwest of Spain)] Chioglossa 2: 91-96. (in Spanish)

Rodewald-Rudescu, L. (1974) Das Schilfrohr. *Phragmites communis* Trinius. [The Common Reed. *Phragmites communis* Trinius] Die Binnengewässer Band 27. 302 p. Stuttgart: Schweizerbart'sche Verlagsbuchhandlung. (in German)

Rose, C. (2011) What makes people tick: the three hidden worlds of settlers, prospectors and pioneers. 420 p. Leicester: Matador.

Rosenthal. G. & Müller, J. (1988) Wandel der Grünlandvegetation im mittleren Ostetal – ein Vergleich 1952-1987. [Change of grassland vegetation in the middle Oste valley – a comparison 1952-1987] Tuexenia 8: 79-99. (in German)

Rößling, H. (2010) Managementstrategien für den Erhalt der Binnensalzstellen in Brandenburg. [Management strategies for the preservation of inland salt areas in Brandenburg] Naturschutz und Landschaftspflege in Brandenburg 19: 45-49. (in German)

Rößling, H., Ruffer, J. & Zauft, M. (2012) Moorschutz mit europäischer Hilfe – Das LIFE-Projekt Kalkmoore Brandenburgs. [Mire protection with European help – the LIFE project 'Calcareous mires of Brandenburg'] Naturschutz und Landschaftspflege in Brandenburg 21: 36-45. (in German)

Rydin, H. & Jeglum, J.K. (2013) The biology of peatlands. 2nd edition. 400 p. Oxford: Oxford University Press.

Salewski, V. & Poluda, A. (2010) Equipping Aquatic Warblers *Acrocephalus paludicola* with geolocators in the Supoy region, Ukraine. Final report. 18 p. Aquatic Warbler Conservation Team (AWCT).

Salewski, V. & Seifert, N. (2010) Searching for the Aquatic Warbler *Acrocephalus paludicola* in the Diawling National Park, Mauritania (with a note on the occurrence of Baillon's Crake *Porzana pusilla*) 23th to 27th January 2010. Unpublished report. 25 p. Aquatic Warbler Conservation Team.

Salewski, V., Canales-Delgadillo, J., Flade, M., Wink, M. & Korb, J. (2012) Eleven new microsatellite loci in the globally threatened Aquatic Warbler (*Acrocephalus paludicola*). Conservation Genetic Resources 4: 279-282.

Salewski, V., Flade, M., Poluda, A., Kiljan, G., Liechti, F., Lisovski, S. & Hahn, S. (2013) An unknown migration route of the 'globally threatened' Aquatic Warbler revealed by geolocators. Journal of Ornithology 154: 549-552.

Schächtele, M. & Kiehl, K. (2005) Einfluss von Bodenabtrag und Mähgutübertragung auf die langfristige Vegetationsentwicklung neu angelegter Magerwiesen. [Influence of topsoil removal and translocation of hay on the long-term vegetation development of newly created nutrient-poor meadows] Naturschutz und Biologische Vielfalt 9: 105-126. (in German)

Schaefer, H.M., Naef-Daenzer, B., Leisler, B., Schmidt, V., Müller, J.K. & Schulze-Hagen, K. (2000) Spatial behaviour of the Aquatic Warbler *Acrocephalus palucidola* during mating and breeding. Journal of Ornithology 141: 418-424.

Schaefer, M. (2006) Brohmer – Fauna von Deutschland. [Fauna of Germany] 809 p. Wiebelsheim: Quelle & Meyer. (in German)

Schäffer, N., Kozulin, A.V., Vergeichik, M.N. (2002a) План управления заказником республиканского значения Званец [Management plan for the zakaznik of national importance Zvaniec] 135 p. Minsk: Ministry of Natural Resources and Environmental Protection of the Republic of Belarus. (in Russian)

Schäffer, N., Kozulin, A.V., Vergeichik, M.N. (2002b) План управления водно-болотным угодьев Дикое [Management plan for Dzikoje wetland] Minsk: Ministry of Natural Resources and Environmental Protection of the Republic of Belarus. (in Russian)

Schäffer, N., Walther, B.A., Gutterridge, K. & Rahbek, C. (2006) The African migration and wintering grounds of the Aquatic Warbler *Acrocephalus paludicola*. Bird Conservation International 16: 33-56.

Schalitz, G., Käding, H. & Leipnitz, W. (1997) Ergebnisse der Renaturierung standorttypischer Grünlandgesellschaften an der unteren Oder. [Results of the restoration of site-typical grassland communities at the Lower Oder Valley] Archiv für Acker- und Pflanzenbau und Bodenkunde 41: 181-188. (in German)

Schalitz, G., Puhlmann, K., Puhlmann, M. (1984): Intensivierung des Überschwemmungsgraslandes an der unteren Oder unter Berücksichtigung gesamtgesellschaftlicher Interessen und der Erhaltung der Ökosysteme. [Intensification of floodplain grassland at the Lower Oder, considering societal interests and ecosystem preservation] Archiv für Naturschutz und Landschaftsforschung Berlin 24: 249-258. (in German)

Schipper, A.M., Zeefat, R., Tanneberger, F., van Zuidam, J. P., Hahne, W., Schep, S.A., Loos, S., Bleuten, W., Joosten, H., Lapshina, E.D. & Wassen, M.J. (2007) Vegetation characteristics and eco-hydrological processes in a pristine mire in the Ob river valley (western Siberia). Plant Ecology 193: 131-145.

Schmidt, M.H., Rocker, S., Hanafi, J. & Gigon, A. (2008) Rotational fallows as overwintering habitat for grassland arthropods: the case of spiders in fen meadows. Biological Conservation 17: 3003-3012.

Schmidt, V., Schaefer, H.M. & Leisler, B. (1999) Song behaviour and range use in the polygamous Aquatic Warbler *Acrocephalus paludicola*. Acta Ornithologica 34: 209-213.

Schoockius, M. (1658) Tractatus de turffi s ceu cespitibus bituminosis. [A treatise on peats as bituminous sods] 256 p. Groningen: Johannes Cöllenus. (in Latin)

Schreiber, K.-F. (1997) Sukzessionen – Eine Bilanz der Grünlandbracheversuche in Baden-Württemberg. [Successions – A summary of the grassland experiments in Baden-Wuerttemberg] 118 p. Karlsruhe: Landesamt für Umwelt, Messungen und Naturschutz Baden-Würtemberg. (in German)

Schulz, K. (2005) Vegetations- und Standortentwicklung des wiedervernässten Grünlandes im Anklamer Stadtbruch (Mecklenburg-Vorpommern). [Vegetation and site conditions of the rewetted grassland in the Anklamer Stadtbruch (Mecklenburg-Vopommern)] 168 p. Diploma thesis. Greifswald: Institut für Botanik und Landschaftsökologie. (in German)

Schulze-Hagen, K. (1991) *Acrocephalus paludicola* (Vieillot 1817) – Seggenrohrsänger. [Aquatic Warbler] In: Handbuch der Vögel Mitteleuropas [Handbook of the birds of central Europe] (ed. by U.N. Glutz von Blotzheim), pp. 252-291. Wiesbaden: Aula. (in German)

Schulze-Hagen, K., Flinks, H. & Dyrcz, A. (1989) Brutzeitliche Beutewahl beim Seggenrohrsänger *Acrocephalus paludicola*. [Prey choices of the Aquatic Warbler *Acrocephalus paludicola* during breeding season] Journal of Ornithology 130: 251-255. (in German)

Schulze-Hagen, K., Leisler, B., Birkhead, T.R. & Dyrcz, A. (1995) Prolonged copulation, sperm reserves and sperm competition in the Aquatic Warbler *Acrocephalus paludicola*. Ibis 137: 85-91.

Schulze-Hagen, K., Leisler, B., Schäfer, H.M. & Schmidt, V. (1999) The breeding system of the Aquatic Warbler *Acrocephalus paludicola* – a review of new results. Vogelwelt 120: 87-96.

Schulze-Hagen, K., Swatschek, I., Dyrcz, A. & Wink, M. (1993) Multiple Vaterschaften in Bruten des Seggenrohrsängers *Acrocephalus paludicola*: Erste Ergebnisse des DNA-Fingerprintings. [Multiple paternities in broods of the Aquatic Warbler *Acrocephalus paludicola*: first results of the DNA-fingerprinting] Journal of Ornithology 134: 145-154. (in German)

Schumann, M. & Mauersberger, R. (2009) Naturschutzorientierte Flachabtorfungen in Kalkflachmooren – ein Erfahrungsbericht aus Nord-Brandenburg. [Topsoil removal in calcareous fens for nature protection – a progress report from North-Brandenburg] Telma 39: 157-174. (in German)

Scientific and Practical Centre for Bioresources (2016) База данных 'Торфяники Беларуси'. [Database 'Peatlands of Belarus'] http://www.peatlands.by; consulted in 01/2017. (in Russian)

Selkoe, K.A. & Toonen, R.J. (2009) Microsatellites for ecologists: a practical guide to using and evaluating microsatellite markers. Ecology Letters 9: 615-629.

Sellin, D. (1989a) Vergleichende Untersuchungen zur Habitatstruktur des Seggenrohrsängers *Acrocephalus paludicola*. [Comparative analyses of habitat structure of the Aquatic Warbler *Acrocephalus paludicola*] Vogelwelt 110: 198-208. (in German)

Sellin, D. (1989b) Hat der Seggenrohrsänger in Mecklenburg noch Überlebenschancen? [Is there any chance of survival for the Aquatic Warbler in Mecklenburg?] Naturschutzarbeit Mecklenburg 32: 31-34. (in German)

Sellin, D. (1990) Zum aktuellen Vorkommen des Seggenrohrsängers *Acrocephalus paludicola* im Oderdelta zwischen Peenestrom und Dzwina. [About the current occurrences of the Aquatic Warbler *Acrocephalus paludicola* in the Oder Valley between Peenestrom and Dzwina] Vogelwelt 111: 181-189. (in German)

Shine, T. (2002) An integrated investigation of the ephemeral wetlands of eastern Mauritania and recommendations for management. PhD thesis. 334 p. Ulster: University of Ulster.

Simberloff, D. (1998) Flagships, umbrellas, keystones: is single-species management passé in the landscape era? Biological Conservation 81: 247-257.

Sirin, A.A., Köhler, S. & Bishop, K. (1998) Resolving flow pathways and geochemistry in a headwater forested wetland with multiple tracers. In: Hydrology, water resources and ecology in headwaters. IASH Publications 248: 337-342.

Sirin, A.A., Shumov, D.B. & Vlasova, L.S. (1997) Investigation of bog water circulation using 3H analysis data. Water Resources 24: 625-633.

Smolders, A.J.P., Lucassen, E.C.H.E.T., Bobbink, R., Roelofs, J.G.M. & Lamers, L.P.M. (2010) How nitrate leaching from agricultural lands provokes phosphate eutrophication in groundwater fed wetlands: the sulphur bridge. Biogeochemistry 98: 1-7.

Sohns, G. & Wawrzyniak, H. (1973) Erfahrungen beim Fangen und Beringen von Seggenrohrsängern (*Acrocephalus paludicola*). [Experiences in catching and ringing of Aquatic Warblers (*Acrocephalus paludicola*)] Beiträge zur Vogelkunde 19: 36-42. (in German)

Spina, F. & Volponi, S., (2008) Atlante della Migrazione degli Uccelli in Italia. 2. Passeriformi. [Atlas of bird migration in Italy. 2. Passeriformes.] Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). 632 p. Rome: Tipografia SCR-Roma. (in Italian)

Stammel, B., Kiehl, K. & Pfadenhauer, J. (2003) Alternative management on fens: Response of vegetation to grazing and mowing. Applied Vegetation Science 6: 245-254.

Statistical Office in Białystok (2015) Podlaskie Voivodship: subregions, powiats and gminas. 311 p. Białystok: Statistical Office.

Steffenhagen, P., Frick, A., Timmermann, T. & Zerbe, S. (2008) Satellitenbildgestützte Bewertung der Stoff-speicherung. [Satellite-based assessment of matter storage] Berichte des IGB (Leibniz-Institut für Gewässerökologie und Binnenfischerei) 26: 155-158. (in German)

Steffenhagen, P., Zerbe, S., Frick, A., Schulz, K. & Timmermann, T (2010) Ökosystemleistungen wiedervernässter Niedermoore in Nordostdeutschland – ein Erfolg aktiven Moorschutzes. [Ecosystem services of rewetted fens in Northeast-Germany – a success of active mire protection] Naturschutz und Landschaftsplanung. 42: 304-311. (in German)

Stepanovich, I.M. (2006) Ecological-phytocoenological monitoring of the fen mires of Polessye. In: Nature of Polessye: peculiarities and perspectives of development (ed. by I.M. Stepanovich & A.F. Stepanovich). Proceedings of the 3rd international scientific conference, Brest 7-9 June 2006. (in Russian)

Stoneman, R. & Brooks, S. (eds) (1997) Conserving bogs: the management handbook. 256 p. Edinburgh: Stationery Office Books.

St-Pierre, P. & Lock, L. (2008) Monitoring of Aquatic Warbler *Acrocephalus paludicola* in southern England in 2007. Report. 21 p. Devon: RSPB, Natural England.

Succow, M. (1982) Topische und chorische Naturraumtypen der Moore. [Topical and chorical landscape types of mires] In: Naturräumliche Grundlagen der Landnutzung, am Beispiel des Tieflandes der DDR [Landscape ecological basics of land use, using the example of the GDR lowlands] (ed. by D. Kopp, K.-D. Jäger & M. Succow), pp. 138-183. Berlin: Akademie-Verlag. (in German).

Succow, M. (2001): Küstenüberflutungsmoore. In: Landschaftsökologische Moorkunde (ed. by M. Succow & H. Joosten), pp. 346-350. Stuttgart: Schweizerbart'sche Verlagsbuchhandlung.

Succow, M. & Joosten, H. (2001) Landschaftsökologische Moorkunde. 2. Auflage. [Landscape ecology of mires. 2nd edition] 622 p. Stuttgart: Schweizerbart Science Publishers. (in German)

Surmacki, A. (2005) Do dense and fast growing crops provide foraging habitats for insectivorous birds? Polish Journal of Ecology 53: 129-133.

Sutherland, W.J. (2002) Conservation biology: openness in management. Nature 418: 834-835.

Szulkin, M. & Sheldon, B.C. (2007) The environmental dependence of inbreeding depression in a wild bird population. PLoS ONE 2: e1027.

Szurdoki, E., Szekeres, R.É., Koczka, K., Bőhm, A., Molnár, A. & Horváth, N.H. (2017) Hungary. EMB Chapter Hungary. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 432-440. Stuttgart: Schweizerbart Science Publishers.

Taczanowski, W. (1883) Ptaki krajowe. Tom 1. [Birds of Poland. Volume 1.] 462 p. Kraków: Akademia Umiejętności.

Tanneberger, F. (2008) The Pomeranian population of the Aquatic Warbler (*Acrocephalus paludicola*) – habitat selection and management. PhD thesis. 186 p. Greifswald: University of Greifswald.

Tanneberger, F. & Wichtmann, W. (eds) (2011) Carbon credits from peatland rewetting. Climate – biodiversity – land use. Science, policy, implementation and recommendations of a pilot project in Belarus. 223 p. Stuttgart: Schweizerbart.

Tanneberger, F., Bellebaum, J., Dylawerski, M., Fartmann, T., Jurzyk, S., Koska, I., Tegetmeyer, C. & Wojciechowska, M. (2011) Habitats of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*) in Pomerania – site conditions, flora, and vegetation characteristics. Plant Diversity and Evolution 129: 253-273.

Tanneberger, F., Bellebaum, J., Fartmann, T., Haferland, H.-J., Helmecke, A., Just, P., Jehle, P. & Sadlik, J. (2008) Rapid deterioration of Aquatic Warbler *Acrocephalus paludicola* habitats at the western margin of its breeding range. Journal of Ornithology 149: 105-115.

Tanneberger, F., Bellebaum, J., Flade, M., Kulbe, J., Sellin, D. & Vegelin, K. (2007) Polnisch-deutsches Life-Projekt zum Schutz des Seggenrohrsängers (*Acrocephalus paludicola*) im Peenetal. [EU-LIFE project for conserving the Aquatic Warbler *Acrocephalus paludicola* in Poland and Germany] Naturschutzarbeit in Mecklenburg-Vorpommern 2: 38-42. (in German)

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.

Tanneberger, F., Bellebaum, J., Helmecke, A. & Minets, M. (2013) Nesting and foraging characteristics of the strongly declining Aquatic Warbler population in Pomerania (NE Germany/NW Poland). Acta Ornithologica 48: 109-118.

Tanneberger, F., Bellebaum, J., Völlm, C., Sellin, D. & Vegelin, K. (2012) Wiesenbrüter im Schilf? – Ergebnisse der sommerlichen Pflegemahd eines LIFE-Projektes im Unteren Peenetal mit Vorschlägen zur Optimierung als Wiesenbrütergebiet. [Meadow birds in the reed? – Results of summerly maintenance mowing of a LIFE project in the lower Peene Valley with a proposal for optimising the area as meadow bird breeding site] Ornithologischer Rundbrief Mecklenburg-Vorpommern 47: 52-65. (in German)

Tanneberger, F., Flade, M., Preiksa, Z. & Schröder, B. (2010a) 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., Flinks, H., Arbeiter, S., Minets, M. & Hegemann, A. (2017) Diet analysis of wetland passerine nestlings using neck collars or faecal sampling produces similar results. Ardea 105: 145-152.

Tanneberger, F., Joosten, H. & Flade, M. (2005) An introduction to Aquatic Warbler conservation in Western Pomerania. In: Anthropogenic influence on wetlands biodiversity and sustainable management of wetlands (ed. by W. Kotowski), pp. 97-106. Warsaw: Warsaw Agricultural University Press.

Tanneberger, F., Joosten, H., Moen, A. & Whinam, J. (2017a) Mire and peatland conservation in Europe. In: Mires and peatlands of Europe (ed. by H. Joosten, F. Tanneberger & A. Moen), pp. 173-196. Stuttgart: Schweizerbart Science Publishers.

Tanneberger, F., Knöfler, V., Linke, W., Tegetmeyer, C. & Kloskowski, J. (2014) Rapid changes in vegetation structure of Aquatic Warbler habitats in Pomerania - outcomes of targeted five year habitat management. Plant Diversity and Evolution 130: 303-313.

Tanneberger, F., Tegetmeyer, C., Busse, S., Barthelmes, A. & 55 others (2017) The peatland map of Europe. Mires and Peat 19: 1-17.

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. Biodiversity and Conservation 18: 1475-1489.

Tanovitskaya, N. (2011) The touristic potential of peatlands. In: Carbon credits from peatland rewetting. Climate – biodiversity – land use. Science, policy, implementation and recommendations of a pilot project in Belarus (ed. by F. Tanneberger & W. Wichtmann), p. 108. Stuttgart: Schweizerbart Science Publishers.

Taylor, R. (1993) Habitat and feeding ecology of *Acrocephalus melanopogon* and the impact of recent fires and management practices at S'Albufera de Mallorca. MSc thesis. 67 p. London: University College, London.

Tegetmeyer, C., Frick, A. & Seifert, N. (2014) Modelling habitat suitability in the Aquatic Warbler wintering ground Djoudj National Park in Senegal. Ostrich 85: 57-66.

Tegetmeyer, C., Herold, B. & Thoma, M. (2016) Monitoring of Aquatic Warbler habitats in the Ndiaël Basin (Senegal). Final report. 58 p. Greifswald: Aquatic Warbler Conservation Team.

Tegetmeyer, C., Thoma, M. & Arbeiter, S. (2012) Moult and mobility of the Aquatic Warbler *Acrocephalus paludicola* on the West African non-breeding grounds. Journal of Ornithology 153: 1045-1051.

Thaxter, C.B., Redfern, C.P.F. & Bevan, R.M. (2006) Survival rates of adult Reed Warblers *Acrocephalus scirpaceus* at a northern and southern site in England. Ringing & Migration 23: 65-79.

Thiele, A., Edom, F. & Liashchynskaya N. (2011) Prediction of vegetation development with and without rewetting. In: Carbon credits from peatland rewetting. Climate – biodiversity – land use. Science, policy, implementation and recommendations of a pilot project in Belarus. (ed. by F. Tanneberger & W. Wichtmann), pp. 42-47. Stuttgart: Schweizerbart Science Publishers.

Timmermann, T., Margóczi, K., Takács, G. & Vegelin, K. (2006) Restoration of Peat-Forming Vegetation by Rewetting Species-Poor Fen Grasslands. Applied Vegetation Science 9: 241-250.

Tischler, F. (1941) Die Vögel Ostpreußens. [The birds of East-Prussia] 331 p. Königsberg, Berlin: Ost-Europa-Verlag. (in German)

Trnka, A., Literák, I., Oldřich, S. & Podzemný, P. (2008) Spring mist-netting of birds in Parížske močiare National Nature Reserve (SW Slovakia). Tichodroma 20: 137-139.

Valkama, E., Lyytinen, S. & Koricheva, J. (2008) The impact of reed management on wildlife: a meta-analytical review of European studies. Biological Conservation 141: 364-374.

Vallotton, L. & Piot, B. (2010) Oiseaux rares et observations inhabituelles en Suisse en 2009. 19e rapport de la Commission de l'Avifaune Suisse. [Rare birds and unusual observations in Switzerland in 2009. 19th report of the Swiss Avifaune Commission] Nos Oiseaux 57: 283-302. (in French)

van der Maarel, E. & Schaminée, J.H.J. (2001) Victor Westhoff (1916-2001). Journal of Vegetation Science 12: 887-890.

van der Spek, V., de Jong, A. & van Winden, E. (2017) The past and present status of migrating Aquatic Warbler (*Acrocephalus paludicola*) in the Netherlands. https://www.turnstones.org/aquatic-warbler; consulted in 03/2018.
van Diggelen, R., Bakker, J.P. & Klooker, J. (1997) Top soil removal: new hope for threatened plant species? In: Species dispersal and land use processes. Proceedings of the 6th annual conference International Association for Landscape Ecology (IALE). 9-11 September (ed. by A. Cooper & J. Power), pp. 257-263. Aberdeen, UK.
van Drunen, Y. & van Verstegen, K. (2008) Ecotourism in semi-natural landscapes - solution for financing nature management? A case study in the Biebrza valley. Crossbill Guides Foundation & Van Hall, Larenstein.
van Eerde, K. (1998) Autumn migration of the Aquatic Warbler *Acrocephalus paludicola* at the Makkumer Zuidwaard in 1986-96. Limosa 71: 149-152. (in Dutch)
van Noordwijk, A.J. & Scharloo, W. (1981) Inbreeding in an island population of the Great Tit. Evolution 35: 674-688.
Vergeichik, L. (2007) Breeding ecology of the Aquatic Warbler *Acrocephalus paludicola* in Belarusian fen mires. PhD thesis. 129 p. Minsk: National Academy of Sciences of Belarus, Institute of Zoology. (in Russian)
Vergeichik, L. & Kozulin, A.V. (2006a) Breeding ecology of Aquatic warbler *Acrocephalus paludicola* in their key habitats in SW Belarus. Acta Ornithologica 41: 153-161.
Vergeichik, L. & Kozulin, A.V. (2006b) 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.
Verhagen, R. (2007) Changing land use: restoration perspectives of low production communities on agricultural fields after top soil removal. PhD thesis. 152 p. Groningen: University of Groningen.
Vogel, A.-L. (2009) Genetische Bestimmung der Herkunft von im Senegal überwinternden Seggenrohrsängern. [Genetic determination of the origin of Aquatic Warblers wintering in Senegal] MSc thesis. Greifswald: University of Greifswald. (in German)
Völlm, C. & Tanneberger, F. (2014) Shallow inundation favours decomposition of *Phragmites australis* leaves in a near-natural temperate fen. Mires and Peat 14: 1-9.
Wagner, A. & Wagner, I. (2005) Leitfaden der Niedermoorrenaturierung in Bayern. [Guidelines for restoration of fens in Bavaria] 114 p. Augsburg: Bayerisches Landesamt für Umwelt. (in German)
Wagner, M., Poschlod, P. & Setchfield, R.P. (2003) Soil seed bank in managed and abandoned semi-natural meadows in Soomaa National Park, Estonia. Annales Botanici Fennici 40: 87-100.
Wagner, N., Reichenbecher, W., Teichmann, H., Tappeser, B., & Lötters, S. (2013) Questions concerning the potential impact of glyphosate-based herbicides on amphibians. Environmental Toxicology and Chemistry 32: 1688-1700.
Walther, B.A., Schäffer, N., Thuiller, W., Rahbek, C. & Chown, S.L. (2007) Modelling the winter distribution of a rare and endangered migrant, the Aquatic Warbler *Acrocephalus paludicola*. Ibis 149: 701-714.
Wassen, M. (1990) Water flow as a major landscape ecological factor in fen development. PhD thesis. 199 p. Utrecht: University of Utrecht.
Wassen, M.J. & Joosten, J.H.J. (1996) In search of a hydrological explanation for vegetation changes along a fen gradient in the Biebrza Upper Basin (Poland). Vegetatio 124: 191-209.
Wassen, M.J. & Olde Venterink, H. (2006) Comparison of nitrogen and phosphorus fluxes in some European fens and floodplains. Applied Vegetation Science 9: 213-222.
Wassen, M.J., Olde Venterink, H., Lapshina, E.D. & Tanneberger, F. (2005): Endangered plants persist under phosphorus limitation. Nature 437: 547-551.
Wawrzyniak, H. & Sohns, G. (1977) Der Seggenrohrsänger. [The Aquatic Warbler] Neue Brehm-Bücherei Bd. 504. Wittenberg Lutherstadt: Ziemsen. (in German)
Weber, C.A. (1907) Wiesen und Weiden an der Oder. [Meadows and pastures at the Oder river] Mitteilungen der Deutschen Landwirtschaftsgesellschaft Stück 8: 89-91. (in German)
Westhoff, V. (1945) Biologische problemen der natuurbescherming. [Biological problems of nature protection] In: Verslagen van de Natuurbeschermingsdag van de N.J.N. te Drachten, pp. 18-30. Drachten. (in Dutch)
Westhoff, V. (1952) The management of nature reserves in densely populated countries considered from a botanical viewpoint. In: Proceedings and papers of the Technical Meeting of the International Union for the Protection of Nature, The Hague, pp. 77-82. Brussels: IUPN.
Wheeler, B.D. & Shaw, S.C. (1995) A focus on fens. Controls on the composition of fen vegetation in relation to restoration. In: Restoration of temperate wetlands (ed. by B.D. Wheeler, S.C. Shaw, W.J. Fojt & R.A. Robertson), pp. 49-72. Chichester: John Wiley & Sons.
White, G.C. & Burnham, K.P. (1999) Program MARK – survival estimation from populations of marked animals. Bird Study 46: 120-139.
Wichmann, S. (2016) Commercial viability of paludiculture: a comparison of harvesting reeds for biogas production, direct combustion, and thatching. Ecological Engineering 103: 497-505.
Wichmann, S. & Köbbing, J.F. (2015) Common Reed for thatching – a first review of the European market. Industrial Crops and Products 77: 1063-1073.

Wichmann, S., Dettmann, S., & Dahms, T. (2016) Agricultural machinery for wet areas. In: Paludiculture – productive use of wet peatlands. Climate protection – biodiversity – regional economic benefits (ed. by. W. Wichtmann, C. Schröder & H. Joosten), pp. 64-70. Stuttgart: Schweizerbart Science Publishers.
Wichtmann, W. & Joosten, H. (2007) Paludiculture: peat formation and renewable resources from rewetted peatlands. IMCG Newsletter 2007/3: 24-28.
Wichtmann, W. & Tanneberger, F. (2009) Feasibility of the use of biomass from re-wetted peatlands for climate and biodiversity protection in Belarus. 113 p. Greifswald: DUENE e.V.
Wichtmann, W. & Tanneberger, F. (2011) Land use options for rewetted peatlands. In: Carbon credits from peatland rewetting. Climate – biodiversity – land use. Science, policy, implementation and recommendations of a pilot project in Belarus. (ed. By F. Tanneberger & W. Wichtmann), pp. 107-110. Stuttgart: Schweizerbart Science Publishers.
Wichtmann, W., Schröder, C. & Joosten, H. (2016) Paludiculture – productive use of wet peatlands. Climate protection – biodiversity – regional economic benefits. 272 p. Stuttgart: Schweizerbart Science Publishers.
Wiedow, D., Burgstaler, J. & Schröder, C. (2016) Influence of harvesting machinery on peat soils. In: Paludiculture – productive use of wet peatlands. Climate protection – biodiversity – regional economic benefits (ed. by. W. Wichtmann, C. Schröder & H. Joosten), pp. 62-63. Stuttgart: Schweizerbart Science Publishers.
Wilson, J.D., Whittingham, M.J. & Bradbury, R.B. (2005) The management of crop structure: a general approach to reversing the impacts of agricultural intensification on birds? Ibis 147: 453-463.
Wojczulanis-Jakubas, K., Chrostek, M.E., Jiguet, F., Martínez, C.Z., Miguélez, D. & Neto, J.N. (2017) Differential timing and latitudinal variation in sex ratio of Aquatic Warblers during the autumn migration. The Science of Nature 104: 101.
Wojczulanis-Jakubas, K., Jakubas, D., Foucher, J., Dziarska-Pałac, J. & Dugué, H. (2013) Differential autumn migration of the Aquatic Warbler *Acrocephalus paludicola*. Naturwissenschaften 100: 1095-1098.
Wołejko, L., Bacieczko, W., Prajs, B., Kowalski, W.W. & Ziarnek, K. (2007) Szata roślinna. [Vegetation] In: Jezioro Miedwie i Nizina Pyrzycka [Miedwie Lake and Pyrzyska Lowland] (ed. by R.K. Borówka), pp. 110-137. Szczecin: Oficyna. (in Polish)
Wróbel, M. & Jurzyk, S. (2004) Habitat conditions of *Carex pulicaris* L. in the Rozwarowo wetlands (western Pomerania). In: The future of Polish mires (ed. by L. Wołejko & J. Jasnowska), pp 85-89. Szczecin: Agricultural University of Szczecin.
Yurkevich, I.D., Golod, D.S. & Aderikho, V.S. (1979) Растительность Белоруссии, ее картографирование, охрана и использование. [The vegetation of Belarus, its mapping, protection and use] 246 p. Minsk: Nauka. (in Russian)
Zak, D. & Gelbrecht, J. (2007) The mobilisation of phosphorous, organic carbon and ammonium in the initial stage of fen rewetting (a case study from NE Germany). Biogeochemistry 85: 141-151.
Zeitz, J. (2016) Drainage induced peat degradation processes. In: Paludiculture – productive use of wet peatlands. Climate protection – biodiversity – regional economic benefits (ed. by W. Wichtmann, C. Schröder & H. Joosten), pp. 7-9. Stuttgart: Schweizerbart Science Publishers.
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 Po-land. Acta Ornithologica 51: 245-256.
Zucca, M. & le CMR (2004) Les observations d'oiseaux migrateurs rares en France. 1er rapport du CMR (juillet 2000-juin 2001). [Observations of rare bird migrants in France. First report of CMR (July 2000-June 2001)] Ornithos 11-5: 193-213. (in French)
Zucca, M. & le CMR (2005) Les observations d'oiseaux migrateurs rares en France. 2e rapport du CMR (janv. 2001-déc. 2002). [Observations of rare bird migrants in France. Second report of CMR (January 2001-December 2002)] Ornithos 12-5: 233-260. (in French)
Zucca, M. & le CMR (2007) Les observations d'oiseaux migrateurs rares en France. 3e rapport du CMR (janv. 2003-déc. 2004). [Observations of rare bird migrants in France. Third report of CMR (January 2003-December 2004)] Ornithos 14-1: 2-33. (in French)
Zucca, M. & le CMR (2009) Les observations d'oiseaux migrateurs rares en France. 5e rapport du CMR (année 2006). [Observations of rare bird migrants in France. Fifth report of CMR (year 2006)] Ornithos 16-1: 2-49. (in French)
Zucca, M., Paul, J.-P. & le CMR (2008) Les observations d'oiseaux migrateurs rares en France. 4e rapport du CMR (année 2005). [Observations of rare bird migrants in France. Fourth report of CMR (year 2005)] Ornithos 15-1: 2-33. (in French)
Zuzuk, F.V., Koloshko, L.K. & Karpyuk, Z.K. (2012) Осушені землі Волинської області та їх охорона. [Drained land of Volyn region and their protection] 294 p. Lutsk: Volin National University. (in Ukrainian)
Zwarts, L. (2010) Will the Inner Niger Delta shrivel up due to climate change and water use upstream? A&W rapport 1537. 36 p. Feanwâlden: Altenburg & Wymenga ecologisch onderzoek.
Zwarts, L., Bijlsma, R., van der Kamp, J. & Wymenga, E. (2009) Living on the edge – wetlands and birds in a changing Sahel. 564 p. Zeist, the Netherlands: KNNV Publishing.

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