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LONG-TERM DECLINE AND HOMOGENIZATION OF AN AVIAN COMMUNITY SURPASSES EFFECTS ON BIRD DIVERSITY CAUSED BY A SINGLE EXTREME FLOOD EVENT

Götz Ellwanger[*1], Olaf van der Geest [1], Jonatan Grimm [1], Jonas Haubrich [1], Darius Stiels [1], Stefan Abrahamczyk [2, 1]

[1]*Ornithologische Arbeitsgemeinschaft Bonn, LIB, Zoological Research Museum Alexander Koenig, Adenauerallee 127, 53113 Bonn, Germany*
[2] *Botanical Garden of the University of Osnabrück, Albrechtstraße 29, 49076 Osnabrück, Germany*
** author for correspondence: sprosser1@web.de*
Orcid-ID Darius Stiels: 0000-0001-7679-9689
Orcid-ID Stefan Abrahamczyk: 0000-0001-8047-932X
Orcid-ID Götz Ellwanger: 0009-0005-8829-7447

Abstract.

Protected areas are key elements in conservation. However, baseline data for these areas is often missing making estimation of biodiversity trends and effectiveness of management difficult to assess. Moreover, severe weather events that are intensified by climate change might heavily affect protected areas. Herein, we analyse breeding bird surveys from a small-scale protected area, the mouth of the river Ahr in western Germany. The area was stroked by a catastrophic flood event in the year 2021. We perform a before-after study spanning 38 years using breeding bird data from the years 1984, 2020 and 2022. Our results show only minor effects caused by the flood event. In contrast, long-term data show an increase of species tight to woody vegetation while open habitat birds, among them more specialist species, often decreased. Hence, the protected area does only partially fulfil its purpose and important gaps are identified. Finally, we conclude that the results of our case study might well be exemplary for many insufficiently managed protected areas and recommend more effective conservation efforts.

Introduction

Biodiversity has suffered from severe declines in Central Europe over the last decades leading to a homogenization of species assemblages (McKinney & Lockwood 1999; Clergeau et al. 2006; Olden & Rooney 2006). While the focus of avian studies often refers to areas under heavy anthropogenic influence, such as agricultural land (Donald et al. 2001; Busch et al. 2020) or cities and associated effects of urbanization (Marzluff 2001; Abrahamczyk et al. 2020) protected areas are of particular interest. Many protected areas in Europe are part of the Natura 2000 network. This network and the underlying Habitats and Birds Directives (Directives 92/43/EEC and 2009/147/EC) aim to maintain the native biodiversity of Europe (Evans 2012). Positive effects of Special Protection Areas (SPA) - the Natura 2000 sites protected under the Birds Directive - have been identified with different effects of region, spatial scale and group of birds studied (Donald et al. 2007; Brodier et al. 2013; Sanderson et al. 2016; Koschová et al. 2018). Populations of common breeding bird species, especially of agricultural habitats, are declining significantly less negative within Natura 2000 sites in France as well as at the EU level than outside (Pellissier et al. 2014; Princé et al. 2021). However, a contrary conclusion was reached by Portaccio et al. (2021) for the Veneto region in northern Italy. Mixed effects of SPA were found in Portugal (Santana et al. 2014; Silva et al. 2018). Gameiro et al. (2020) show a lower rate of loss of steppe habitats in SPAs compared to unprotected areas on the Iberian Peninsula. They trace the loss of steppe habitats even within SPAs back to inadequate agri-environmental practice. Gerritsen et al. (2020) identified a need for improvement with regard to the definition of conservation objectives and measures, stakeholder participation, better use of financial resources, and more results-oriented management.

Nevertheless, so far, an assessment of the effectiveness of site management has been carried out for only a small proportion of Natura 2000 sites. Although the Birds Directive was adopted in 1979, most of the SPA were not included in the Natura 2000 network until the early 2000s. Decades before, many protected areas were established on the basis of national or federal laws, often without a detailed analysis of current or past biodiversity inventories. Thus, original data on biodiversity from today's SPA are often missing, leading to potentially biased population trends and a shifting baseline due to declines of species abundance or the local extinction of species occurring before the legal protection by European laws (Papworth et al. 2009; Bonebrake et al. 2010; Soga & Gastron 2018).

While species abundance and community composition might change slowly over longer time periods, single short-term disturbance events can have strong influences. Even the shift of ecosystems from one state into another has been observed (Burton et al. 2020). These events can

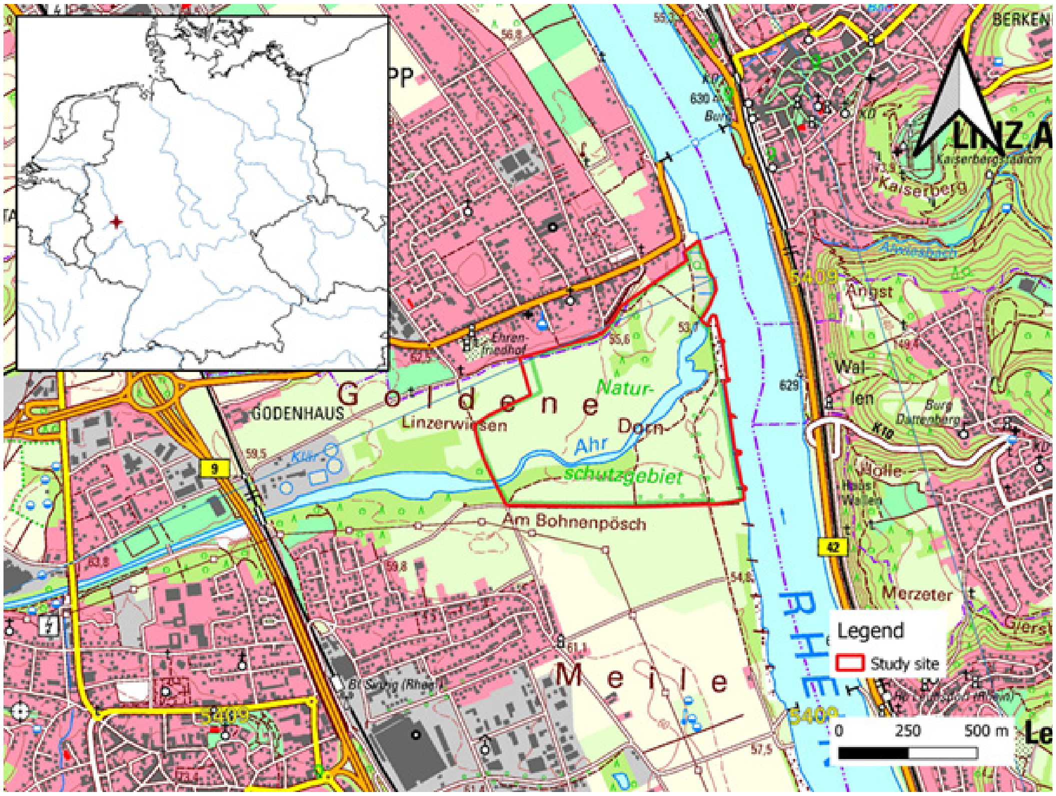

Figure 1: Study site (red line) at the mouth of the river Ahr. The insert shows the location (red star) within Central Europe. Map source: ©GeoBasis-DE / LVermGeoRP (2024), dl-de/by-2-0, http://www.lvermgeo.rlp.de.

happen on different spatial and temporal scales (Forman 1995; Burton et al. 2020). From an avian perspective, an event affecting a small area would influence single individuals or a couple of breeding pairs and therefore only slightly increase mortality or reduce productivity. A well-known small-scale example might be a landslide or a treefall gap (Levey 1998). Such events with limited spatial extension might occur often in a given area of reasonable size, and hence, are comparatively easy to study. In contrast, events affecting biodiversity on a medium to landscape level are more challenging but still well-known as long as they occur regularly. This includes yearly flood events occurring on natural rivers throughout Central Europe. In contrast, more irregular events like wild fires (Anonymus 2019), hurricanes (Gardner et al. 2005) but also extraordinary heavy floods (Resh et al. 1988; Poff 2002; Death et al. 2015) are much less predictable. The latter might have even more severe consequences along rivers that are straightened and where the floodplain is partly or completely disconnected from the river itself. While regular floods are typically limited in water height as well as load of sediment and debris, devastating floods on medium-sized rivers that hitherto occur at intervals of centuries or millennia have been rarely studied. In addition, the likelihood of extreme flood events increases due to climate change (Seneviratne et al. 2021, Tradowsky et al. 2023), which potentially increases their effects on biodiversity.

Herein, we present one of the few before-and-after studies of the effects of an extreme flood event from the breeding bird community of the mouth of the river Ahr in Germany, an area protected as SPA under EU legislation as well as under federal law. At the same time, we compare the effects of the extreme flood of 2021 with long-term changes of the local breeding bird community over a period of around 40 years. By comparing these time frames, we aim to analyse changes in species composition and community characteristics on a) long-term, i.e. between 1984 and 2020/2022 and b) to derive information on the short-term most likely heavily influenced by the flood of July 2021. Our hypotheses are that 1) given the protected nature of the area, long-term changes are positive or less severe than those seen elsewhere. 2) We expect that the extreme flood reduced bird species composition and total abundance in our study site.

Material and Methods

Study Site

Our study area covers the nature reserve at the mouth of the river Ahr, a western tributary of the river Rhine. It is situated in the north of the German federal state of Rhineland-Palatinate in the district of Ahrweiler (Figure 1). It is part of the lower Middle Rhine area, which is characterized by temperate climate with warm summers and mild winters (Fischer 1981). The study site was designated as a nature protected area (NPA) in 1977 with a size of 55 ha (Hoppe 1986) and extended to the current size of 63 ha in 1981 (Landkreis Ahrweiler 1981). It belongs to the

Natura 2000 network as part of the Site of Community Importance (SCI) DE5409301 "Mündungsgebiet der Ahr" as well as part of the SPA DE5409301 "Ahrmündung".

The Ahr is the only tributary of the Rhine that still meanders freely in parts of its estuary despite hydraulic engineering changes (Hoppe 1986). It is delta-shaped and buried in the low terrace of the Rhine and is subject to a continuous interplay between the Rhine and the Ahr. During Rhine floods, parts of the area are temporarily flooded up to the western NPA border due to backwater. As a result of the reduced flow velocity, the Ahr then accumulates gravel and sand banks that can exceed the average water level of the river. When the water level of the Rhine becomes normal again, the Ahr regains its gradient and the deposited materials are removed over time, including the embankments broken off by lateral erosion (Hoppe 1986). Thanks to land purchases by the public sector between 1979 and 1981 as well as restoration measures carried out between 2003 and 2004 west of the NPA boundary, the Ahr can meander freely in the NPA and has re-developed its natural river dynamics (Büro Dr. Froehlich 2016a, b; Landesamt für Umwelt Rheinland-Pfalz 2016).

Along the Ahr and the Rhine, the area is covered by softwood riparian forest, a poplar plantation, avenue trees, and tall herbaceous vegetation, which occupy about half of the NPA. The remaining areas are mainly used as grassland. Grassland south of the Ahr as well as in the northeast of the NPA consists of intensively used hay meadows. North of the Ahr the landscape is a small-scale mosaic of horse pastures, more or less extensively used hay meadows, scattered orchard remnants, hedges and bushes, abandoned orchards and gardens (Büro Dr. Froehlich 2016a, b; Landesamt für Umwelt Rheinland-Pfalz 2016).

The aim of protection as an NPA and Natura 2000 sites is to preserve or restore the natural dynamics of watercourses and riparian zones, their typical habitats and structures consisting of shifting alluvial deposits and alluvial forest stands, as well as embedding them in surrounding non-intensively used species-rich grassland (Büro Dr. Froehlich 2016b; Landesamt für Umweltschutz und Gewerbeaufsicht 1986).

Flood event

Following long-lasting rain, a catastrophic flood event hit parts of Western Europe affecting parts of Belgium, the Netherlands and Western Germany during the night of 14th to 15th July 2021. The Ahr valley in Rhineland-Palatinate (Germany) was particularly struck. At least 133 people died (de.wikipedia.org, last access 2023-10-29) and devastating damages on more than 3,000 buildings and infrastructure was reported. The NPA at the Ahr mouth was affected directly by the flood due to the destruction of trees and shrubs close to the river as well as by washed ashore rubbish. In the following, it was also affected by cutting additional shrubs at the southern side of the Ahr during later restoration works that were conducted to remove large amounts of partly toxic rubbish.

Bird data

The study site was repeatedly surveyed using territory mapping of birds (Bibby et al. 1995; Südbeck et al. 2005), namely in 1984, 2020 and 2022. The first breeding bird survey of the area was conducted by Koch (1984), who covered a study area about twice as large as the NPA from March to July 1984. Methodologically it was very similar to standard mapping methods and included eleven complete surveys making it comparable to successive approaches.

Fieldwork was conducted by JH in 2020 (Haubrich 2020) and by GE, JG, OG, SA, and Martina Harms in 2022. In both years the total area of the NPA was surveyed ten times between mid-March and early July. In order to record woodpeckers, a playback recording was used while conducting surveys in March. In addition, in 2022 GE mapped Little Owls *Athene noctua* on three evenings using a playback recording (Ellwanger & Woitol 2023). JH evaluated the number of breeding territories based on the field data in 2020 while DS and GE identified the number for the 2022 data.

We used the classification of ecological traits for the bird species of Germany (Wahl et al. 2014) to relate six habitat categories to all recorded species of breeding birds: residential area, open land (orchards, ruderal area, meadows), tall growing herbaceous vegetation, riparian forest, water bodies and several habitat types (generalist). We selected this classification scheme because it is widely used by the Dachverband Deutscher Avifaunisten (umbrella organisation of German ornithologists) and the local scope of our study.

Habitat data

The vegetation of the NPA was mapped in 1984 (Landesamt für Umweltschutz und Gewerbeaufsicht 1986). We summarized some vegetation types from the 1984 study into eight main habitat categories: water body (river), pioneer vegetation on gravel banks, arable field, grassland (hay meadow and pasture), tall herbaceous permanent ruderal vegetation, gardens, overgrown orchards and woody vegetation including riparian forest and poplar stands (Fig. S1). The area of the different habitat types was calculated for 1984 by digitalizing the vegetation map of Landesamt für Umweltschutz und Gewerbeaufsicht (1986). For habitat cover before and after the flood event we used aerial photos from the 27th June 2019 and 3rd September 2021 (Source: Geobasisinformationen der Vermessungs- und Katasterverwaltung Rheinland-Pfalz, © 2021). Data processing and calculations were performed using QGIS 3.22 Białowieża (QGIS Association, http://www.qgis.org).

Statistical analyses

We compared long-term changes (1984 vs. 2020 and 1984 vs. 2022) of the breeding bird assemblage over time as well as of the cover of habitat types in the NPA to the flood-induced short-term changes (2020 vs. 2022) by calculating Bray-Curtis dissimilarity indices for each of the mentioned data pairs. Additionally, we computed Sorensen diversity and species evenness indices of the bird assemblages observed in 1984, 2020 and 2022 based on the breeding habitats of the individual species to identify species groups with the strongest positive and negative trends. These analyses were also performed for the cover of habitat types in the different years.

Finally, we conducted a Fisher´s exact test to document the impact of the flood on the abundance of riparian forest species (comparing the abundance per species among 2020 and 2022). Riparian forest species were classified based on the habitat categories defined by Wahl et al. (2014). These species mostly breed in the riparian forest, the habitat type affected by the flood most heavily. All statistical tests were conducted in R 3.4.3 (R Development Core Team 2017).

Table 1: Number of breeding pairs per species observed in 1984, 2020 and 2022 as well as breeding habitat categories for the species.

Scientific Name	English Name	Breeding Pairs 1984	Breeding Pairs 2020	Breedings Pairs 2022	Breeding Habitat Category
Accipiter nisus	Eurasian Sparrowhawk			1	Riparian forest
Acrocephalus palustris	Marsh Warbler	38	16	16	Tall-growing herbaceous vegetation
Acrocephalus scirpaceus	Reed Warbler	2	2	2	Tall-growing herbaceous vegetation
Aegithalos caudatus	Long-tailed Tit		8		Riparian forest
Alauda arvensis	Common Skylark	1			Openland
Alcedo atthis	Kingfisher	1	2	2	Water bodies
Alopochen aegyptica	Egyptian Goose		2	1	Water bodies
Anas platyrhynchos	Mallard	4	4	3	Water bodies
Athene noctua	Little Owl		3	3	Openland
Branta canadensis	Canada Goose		2	1	Water bodies
Carduelis carduelis	European Goldfinch	10	9	4	Openland
Certhia brachydactyla	Short-toed Treecreeper	7	13	9	Riparian forest
Charadrius dubius	Little Ringed Plover	1			Openland
Chloris chloris	Greenfinch	6	1	1	Settlements
Coccothraustes coccothraustes	Hawfinch		2		Riparian forest
Columba oenas	Stock Dove			2	Riparian forest
Columba palumbus	Common Wood Pigeon	11	6	13	Generalist
Corvus corone	Carrion Crow	4	1	1	Generalist
Cuculus canorus	Common Cuckoo	1			Openland
Cyanistes caerueleus	Blue Tit	14	23	22	Riparian forest
Cygnus olor	Mute Swan	2			Water bodies
Dendrocopos major	Great Spotted Woodpecker		6	4	Riparian forest
Dryobates minor	Lesser Spotted Woodpecker			1	Riparian forest
Emberiza citrinella	Yellowhammer		10	4	Openland
Emberiza schoeniclus	Common Reed Bunting	3			Tall-growing herbaceous vegetation

Erithacus rubecula	European Robin	1	17	15	Riparian forest
Fringilla coelebs	Chaffinch	22	12	14	Riparian forest
Garrulus glandarius	Eurasian Jay		2	2	Riparian forest
Hippolais icterina	Icterine Warbler	1			Openland
Hippolais polyglotta	Melodious Warbler		1		Openland
Lanius collurio	Red-backed Shrike		1	1	Openland
Linaria cannabina	Common Linnet	1			Generalist
Locustella naevia	Common Grasshopper Warbler	3	2	3	Tall-growing herbaceous vegetation
Luscinia megarhynchos	Common Nightingale		11	11	Generalist
Milvus migrans	Black Kite		1	1	Openland
Motacilla alba	White Wagtail	3	2	2	Settlements
Motacilla cinerea	Grey Wagtail	1	1	1	Water bodies
Muscicapa striata	Spotted Flycatcher	12	2	1	Openland
Oriolus oriolus	Eurasian Golden Oriole	2		1	Riparian forest
Parus major	Great Tit	16	26	25	Riparian forest
Passer domesticus	House Sparrow	1			Settlements
Passer montanus	Tree Sparrow	20	1		Settlements
Phasianus colchicus	Common Pheasant	3	2		Openland
Phoenicurus phoeni-curus	Common Redstart	2			Openland
Phylloscopus collybita	Chiffchaff	7	32	22	Riparian forest
Phylloscopus trochilus	Willow Warbler	5			Riparian forest
Pica pica	Eurasian Magpie	1	1	1	Settlements
Picus viridis	European Green Woodpecker		3	3	Riparian forest
Poecile montanus	Willow Tit	3	1		Riparian forest
Poecile palustris	Marsh Tit		4		Riparian forest
Prunella modularis	Dunnock	10	19	27	Generalist
Pyrrhula pyrrhula	Bullfinch		2		Riparian forest
Serinus serinus	Serin	14	2	2	Settlements
Sitta europaea	Eurasian Nuthatch		6	2	Riparian forest
Streptopelia turtur	European Turtle Dove	1			Riparian forest
Sturnus vulgaris	Common Starling	24	21	20	Openland
Sylvia atricapilla	Blackcap	6	53	46	Riparian forest
Sylvia borin	Garden Warbler	12	11	8	Riparian forest
Curruca communis	Common Whitethroat		16	12	Openland
Troglodytes troglodytes	Eurasian Wren	13	27	29	Riparian forest
Turdus merula	Common Blackbird	49	18	24	Generalist
Turdus philomelos	Song Thrush	2	12	22	Riparian forest
Turdus pilaris	Fieldfare	15	1	3	Openland
	Total Number of Breeding Pairs	**355**	**420**	**388**	
	Number of Breeding Species	**43**	**48**	**44**	

Results

The number of breeding bird species in the NPA remained approximately constant over the study period (Table 1). While in 1984 43 species were registered, 48 species were found in 2020 and 44 in 2022. In contrast, the total number of breeding pairs (including all bird species) increased from 355 pairs in 1984 to 420 in 2020 and decreased to 388 pairs in 2022. However, the marked changes occurred in species composition: Between 1984 and 2020 twelve species got locally extinct and 17 species newly colonized the NPA. Between 2020 and 2022 further eight species became locally extinct and four newly colonized the NPA. Most of the locally extinct as well as of the newly colonizing species bred in the NPA only in small numbers. Exceptions are the Tree Sparrow *Passer montanus* (Linnaeus, 1758) that was common in 1984 (20 pairs) and became extinct in 2022. The Common Nightingale *Luscinia megarhynchos* Brehm, CL, 1831 did not occur in the NPA ”Mündungsgebiet der Ahr” in 1984 while 11 pairs were recorded in 2020 and 2022 each.

However, many more species showed changes in abundance (Table 1): The 10 % of the species that showed the strongest total increase between 1984 and 2020 and 1984 and 2022, respectively are Eurasian Blackcap *Sylvia atricapilla* (Linnaeus, 1758), Common Chiffchaff *Phylloscopus collybita* (Vieillot, 1817), European Robin *Erithacus rubecula* (Linnaeus, 1758), Common Whitethroat *Curruca communis* (Latham, 1787), Eurasian Wren *Troglodytes troglodytes* (Linnaeus, 1758), Common Nightingale, Song Thrush *Turdus philomelos* Brehm, CL, 1831 and Dunnock *Prunella modularis* (Linnaeus, 1758) with only small differences from 2020 to 2022. On the other hand, the 10 % of species that showed the strongest total decreases between 1984 and 2020 respectively 1984 and 2022 are Common Blackbird *Turdus merula* Linnaeus, 1758, Marsh Warbler *Acrocephalus palustris* (Bechstein, 1798), Tree Sparrow, Fieldfare *Turdus pilaris* Linnaeus, 1758, European Serin *Serinus serinus* (Linnaeus, 1766), Spotted Flycatcher *Muscicapa striata* (Pallas, 1764) and Eurasian Chaffinch *Fringilla coelebs* Linnaeus, 1758. While the strongly increasing species are mostly common breeding birds of the forest understory, many strongly decreasing and extinct species are typical representatives of the open, cultural landscape and rural areas, showing general population declines in Central Europe.

There is only minor variation in the abundance of breeding pairs between 2020 and 2022 in all kinds of habitats. Even though the riparian forest was most strongly affected by the devastating flood in 2021, the frequency of forest species breeding in the riparian forest decreased (in total 260 pairs (2020) vs. 228 pairs (2022)) but was not changed significantly between 2020 and 2022 (Fisher´s exact test: $p = 0.1114$).

The long-term changes in species composition of breeding birds in the NPA are also reflected in the Bray-Curtis analyses (Table 2). Comparing the assemblages of 1984 and 2020 as well as the assemblages of 1984 and 2022 we found a dissimilarity of 52.25% and 49.39%, respectively. In contrast, the dissimilarity of the bird assemblages between 2020 and 2022 accounted only for a dissimilarity of 26.37%. Changes in species composition did not occur equally among species groups (Table 1): While the number of breeding pairs of settlements, open landscapes and tall herbaceous vegetation decreased strongly between 1984 and 2022, the number of breeding pairs of riparian forest increased considerably. Furthermore, we report decreasing Shannon diversity indices as well as evenness values (Table 3).

Table 2: Dissimilarity (Bray-Curtis) analyses of the bird assemblages and habitat types in the NPA “Mündungsgebiet der Ahr” among years.

Assemblage	Years	Dissimilarity
Birds	1984-2020	52.25 %
Birds	1984-2022	49.39 %
Birds	2020-2022	26.37 %
Habitat types	1984-2020	21.57 %
Habitat types	1984-2022	18.58 %
Habitat types	2020-2022	5.78 %

In contrast to the long-term changes in the bird assemblage between 1984 and 2020/2022, habitat changed much less severe based on area of selected categories (1984 vs. 2020: 21.57 %, 1984 vs. 2022: 18.58 %; Bray-Curtis dissimilarity analyses). Intensively used habitat types (arable fields & managed gardens) that were already rare in 1984 strongly decreased, but also tall herbaceous vegetation and pioneer vegetation on gravel banks declined. Intensively used habitat types were mostly transformed into grassland or started to overgrow. However, the largest increase (+241% / +178 %) was observed in the area covered by

Table 3: Species number, number of breeding pairs in total and per breeding habitat type, Shannon diversity index and Evenness for bird abundances among species groups of the six breeding habitat types in the three surveys of breeding birds in the NPA ”Mündungsgebiet der Ahr”.

	1984	2020	2022
Number of species & (breeding pairs)	43 (355)	48 (420)	44 (388)
Generalist	5 (75)	5 (55)	5 (76)
Water bodies	4 (8)	5 (11)	5 (8)
Tall-growing herbaceous vegetation	4 (45)	3 (20)	3 (21)
Openland	10 (71)	11 (67)	9 (49)
Riparian forest	14 (111)	19 (260)	18 (228)
Settlements	6 (45)	5 (7)	4 (6)
Shannon diversity index	1.623	1.165	1.195
Evenness	0.906	0.65	0.667

Table 4: Cover of habitat types (m²) among study periods in the NPA "Mündungsgebiet der Ahr".

	1984	2020	2022
Water body	28,398	17,901	27,890
Pionier vegetation	42,827	11,137	27,291
Tall herbacous vegetation	118,477	91,494	98,615
Grassland	247,383	263,482	261,710
Arable field	61,621	0	0
Garden	12,221	2,918	2,918
Overgrown orchard	14,774	19,905	19,682
Riparian forest	49,169	168,026	136,780
Shannon diversity index	1.656	1.337	1.436
Evenness	0.796	0.687	0.738

riparian forest (Figure 2). Overall, minor habitat changes are also reflected in the slightly decreasing Shannon diversity indices and evenness values (Table 4).

On the short-term (2020 vs. 2022), we found only a very small impact of the flood on the cover of the different habitat types (dissimilarity of 5.78 %). The area covered by the riparian forest decreased while the area of water bodies and pioneer vegetation increased. These changes are about five times lower than the relative changes in the bird assemblage (2020 vs. 2022: 26.37 % dissimilarity).

Discussion

The long-term changes of the bird community at the protected river mouth of the Ahr exceed effects of the single catastrophic flood event of 2021. Over a long period (36/38 years), turnover of species was more pronounced than actual change in number of species or breeding pairs. As we only look at three points in time our data are possibly prone to some extent of year-to-year variation. Hence, we draw conclusions carefully and focus our discussion on the most noticeable and obvious results.

Short-term changes

In contrast to our expectations, the catastrophic flood of 2021 did not drastically change the riverside vegetation or the bird community in the study area. The flood happened mid-July after the breeding season of most species, so that direct effects on local productivity might have been small. Given the local extent of the event, which was mainly limited to the river valley immigration from surrounding areas is also likely. Moreover, we did not observe an avoidance of the direct proximity of the river as recorded elsewhere during flood years (Jankowiak & Ławicki 2014). Thus, even though overall abundance of typical forest understory species decreased, individual species showed variable trends with positive as well as

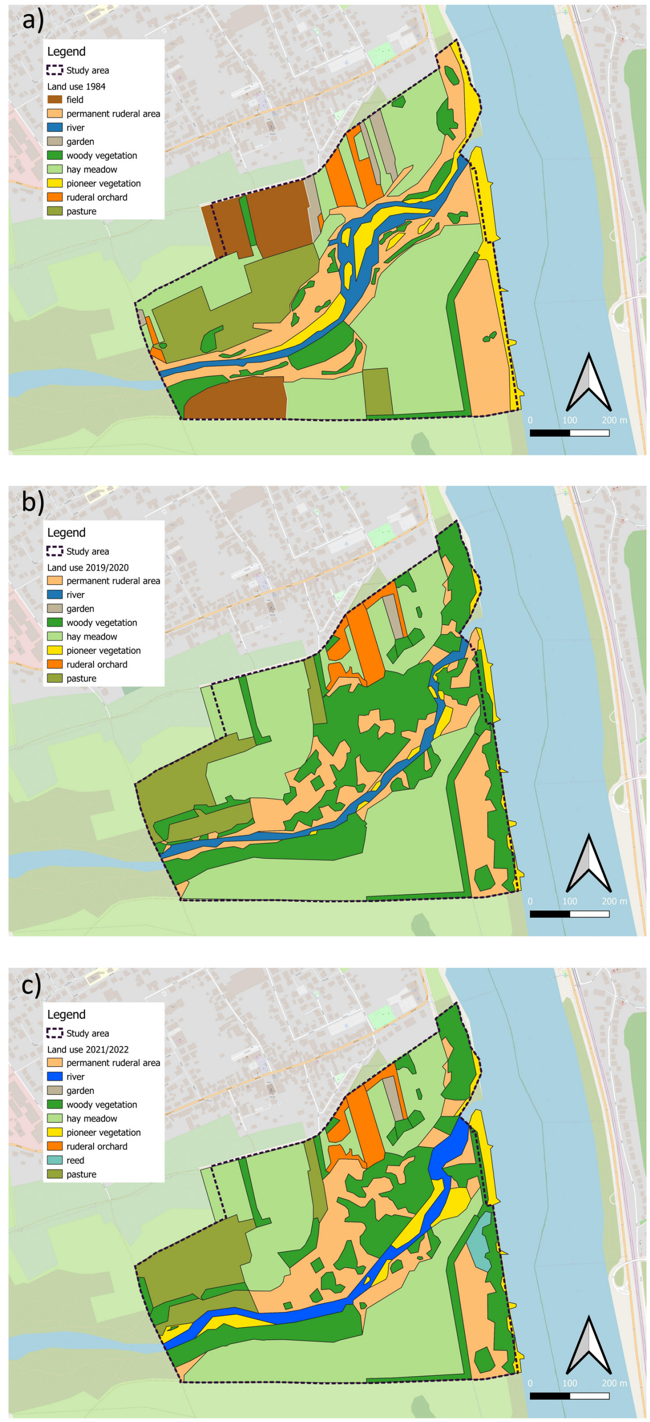

Figure 2: Land use in a) 1984, b) 2019/2020 prior to the flood and c) 2021/2022 after the flood. Background map showing current situation outside the study area for orientation only (Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org).

negative changes. These changes may at least partly be explained by inter-annual variation.

However, it is necessary to stress that our study site is not representative for the entire Ahr valley. Upstream, destructions were often much more severe, especially in the narrow V-shaped valley above Walporzheim where almost all bushes, trees, vines and even forest patches were torn from the bottom of the valley.

Long-term changes

Bird composition has greatly changed from 1984 to 2020/2022 in the NPA at the Ahr mouth. Our results are similar to other studies that showed a strong species turnover combined with a sneaking species loss but stable or even increasing numbers of breeding pairs (e.g. Abrahamczyk et al. 2021). Increases and decreases of the 10% quantile of a bird assemblage are often mirrored in national (Gerlach et al. 2019) or even European trends (https://pecbms.info/, last access 31.01.2024) for the same species. In general, species with increasing populations inhabit forests or at least wooded areas while those with negative population trends are rather inhabiting the open, structurally rich cultural landscape (Donald et al. 2001, 2006; Heldbjerg et al. 2018; Kamp et al. 2020). This general homogenisation of bird assemblages (Marzluff 2001; Murgui & Hedblom 2017) only holds partly for the assemblage in our study site: Similar to other regions forest understory species increased at the NPA at the Ahr mouth while open habitat species decreased. Surprisingly, some species of more open landscapes newly inhabited our study area since 1984. Common Whitethroat, Common Nightingale, and Little Owl established new, stable populations and may have benefited from the increased overgrowth of the former gardens. In contrast, the majority of open habitat species suffered from the increase of shrubbery and riparian forest, such as the Tree Sparrow, Marsh Wabler or Willow Wabler *Phylloscopus trochilus* (Linnaeus, 1758). Additionally, the decreasing trend of the Common Blackbird, which inhabits different habitat types, might be a consequence of outbreaks of the Usutu-Virus in the last years though this remains speculative (Bosch et al 2012; Lühken et al. 2017; Vilibic-Cavlek et al. 2020).

Implication for conservation

Our study site is a protected area where active conservation measures have been implemented to improve habitat quality. One aim was the increase of the area of floodplain forest (Büro Dr. Froehlich 2016b; Hoppe 1986; Landesamt für Umweltschutz und Gewerbeaufsicht 1986). Neither the management plans of the NPA nor the SCI contain exact target values for the area of habitats, but according to Burkhardt et al. (1994) the area of riparian forests should not fall below 20 ha. This aim has been partially achieved and naturally population of riparian forest birds increased likewise. However, simultaneously a transformation of the area towards the needs of species of more open habitats was warranted. This second aim, which was supported by the development of only a few, small, species-rich flood plain meadows largely failed since most species of open habitat decreased or even became extinct and few new species of conservation priority established. Additionally, threatened former breeding species such as Corn Crake *Crex crex* (Linnaeus, 1758) and Bluethroat *Luscinia svecica* (Linnaeus, 1758) did not return to this day (Rheinwald et al. 1984; Landesamt für Umweltschutz und Gewerbeaufsicht 1986).

Furthermore, the nitrophilous meadows south of the Ahr as well as in the north east of the reserve are currently largely avoided of breeding birds and show a depauperated flora (SA, personal observation). These meadows are commonly trespassed by people with dogs. Birds only occasionally visit them for feeding. In this area, which covers about a quarter of the reserve, there is a contract for management with the aim of extensification (regulation of mowing times, ban on fertilization and pesticide use). Development is likely to take a long time due to heavily fertilized soils and has not yet been successful (Büro Dr. Froehlich 2016a). Evaluating these results, we conclude that the NPA "Mündungsgebiet der Ahr" is not able to conserve its avian community. Two different interpretations of this conclusion are possible, which are not mutually exclusive: 1) Intrinsic factors are eminent – the protected area is too small or not sufficiently managed, 2) trends in protected areas cannot be decoupled from overall large-scale trends. The second interpretation cannot entirely dismissed but would suggest that the European protected area network as a whole is insufficient to mitigate overall trends, at least for common species (but see Princé et al. 2021). Some studies pointing to species conservation success stories, including those in floodplain areas, argue against the second interpretation (Brodier et al. 2013; Kajtoch & Figarski 2013; Pellissier et al. 2014; Utschick 2014; Princé et al. 2021). However, the observed situation likely mirrors the conditions of many strictly protected areas in Germany and beyond (Leverington et al. 2010; Haarmann & Pretscher 1993; Santana et al. 2014; Haupt 2015; Silva et al. 2018; Geldmann et al. 2019; Maxwell et al. 2020; Portaccio et al. 2021, Pflüger et al. 2024). Moreover, the positive long-term trend in number of breeding pairs contradicts results from regional to continental studies (Bauer et al. 2019, Burns et al. 2021). However, it is indisputable that the implementation of conservation measures in our study area, but also in numerous other protected areas (especially to improve the habitats of protected species) still needs to be considerably improved (Pellissier et al. 2014, Milieu et al. 2016, Portaccio et al. 2021, Prince et al. 2021).

Potential solutions based on best practice examples already exist elsewhere and can be transferred to the Ahr mouth. For example, trophic rewilding (Svenning et al. 2016) has been identified as a key factor to counteract the biodiversity crisis (Svenning 2020; Hart et al. 2023). Large herbivores such as water buffalos kept in low density can shape landscape and biodiversity in a desired way and are used for landscape conservation in other protected areas (Krawczynski et al. 2008; Bunzel-Drüke et al. 2019). They have the potential to be an attraction for locals and touristic visitors from nearby areas, while necessary fences would also keep off trespassing people and their dogs (Bunzel-Drüke et al. 2019). Such a grazing project was proposed for the study area by the responsible nature conservation authority in 2018, but was initially postponed due to the 2021 flood event. Naturally, any changes in management necessarily need the consideration of different interests of stakeholders and will be associated with financial costs. However, given the current situation of the local biodiversity and the likelihood for future floods an improvement of current management will benefit nature and people at the mouth of the river Ahr.

Final remarks

Originally, we were mainly interested in the effects of an extraordinary flood event on a local bird community. However, while conducting the study and analysing the results it became clear that our results might have additional implications for conservation of strictly protected areas. We would like to motivate other researchers to publish their results of mid- to long-term biodiversity inventories beyond reports and grey literature to make their knowledge accessible to the scientific community as well as practitioners and the public.

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