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Using literature and expert knowledge to determine changes in the bird community over a century in a Turkish wetland

Dilara Arslan^{A,B,*} , Lisa Ernoul^A , Arnaud Béchet^A , Ömer Döndüren^C, Mehmet Siki^D and Thomas Galewski^A

ABSTRACT

Context. Bird species have been studied and documented abundantly in the past decades and are good indicators of ecosystem conditions, providing useful information of the changes in the ecological state of wetlands over time. However, monitoring data for birds in wetland sites are often disparate and not homogeneous over time and among species, which complicates the interpretation of trends. **Aims.** We examined historical literature from 1835 to 2019, complemented by an expert knowledge survey and citizen-science databases to estimate the abundance of species, and evaluated changes in the structure and composition by average bird abundances. **Key results.** Our results suggested that land-cover and land-use changes have shaped the local bird community, with a decline in agricultural and grassland bird species as a result of changes in agricultural practices. Coastal wetland and marine birds have increased in abundance, most probably linked to the extension of saltpans and successful conservation measures. **Conclusions.** These trends in bird communities demonstrate the impacts of different land management strategies on biodiversity. **Implications.** This methodology can be replicated in other Ramsar and wetland sites around the world to raise new conservation issues and improve site conservation.

Keywords: agricultural practices, bird trends, expert knowledge, Gediz Delta, historical ecology, multi-species index, saltpans, wetlands.

Introduction

Human activities threaten biodiversity at the global scale ([Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services 2019](#)). Wetlands are one of the most threatened ecosystems, with three times higher losses than in forest ecosystems ([Ramsar Convention on Wetlands 2018](#)). As much as 87% of global wetlands have been lost since the 1700s, with four times more destruction during the 20th century than in the 19th century ([Davidson 2014](#); [Ramsar Convention on Wetlands 2018](#)). The remaining 12.1×10^6 km² of wetlands around the world continue to be threatened by urban sprawl, water abstraction, pollution, and agricultural intensification ([Underwood *et al.* 2009](#); [Darwall *et al.* 2014](#); [Davidson 2014](#); [Perennou *et al.* 2018](#)). Destruction and degradation of Mediterranean wetlands contribute significantly to biodiversity loss because wetlands accommodate a higher ratio of species per hectare than do other ecosystems in the region. In the Mediterranean basin, more than 30% of vertebrate species are dependent on wetlands that cover only 2–3% of the land surface of this region ([Geijzendorffer *et al.* 2018](#)). So as to reduce these threats and conserve wetlands and their associated biodiversity, the Ramsar Convention was adopted in 1971 and is now ratified by more than 170 countries. Additionally, various other international agreements have been adopted to protect wetland species, including Convention on International Trade in Endangered Species (CITES), Convention on Biological Diversity (CBD), and Convention on Migratory Species (CMS; [Christoffersen 1997](#)).

Human activities have modified the structure, composition and dynamics of species assemblages in wetlands ([Boylan and MacLean 1997](#); [Gibbs 2000](#)). At the site level, the detection of such biodiversity changes can help prioritise management decisions or

conservation actions, but it requires a good knowledge of the long-term evolution of species communities (Bonebrake *et al.* 2010). To evaluate such long-term trends, it is necessary to have adequate information on both species abundance and richness (here species richness is considered as the number of species within a defined region; Loh *et al.* 2005; Teyssèdre and Robert 2015). In many sites, the lack of systematic data prevents making sound comparisons between the present and the past states (Pocock *et al.* 2015); however, this may vary depending on the taxa considered. Fortunately, birds have received the attention of many pioneering naturalists and early academic ecologists, even in less developed countries, so comparing the bird community of a site over different time scales is often feasible and can provide insights into the changing conditions in a site (Galewski and Devictor 2016).

In Turkey, wetlands follow the same global trend. Here, over 1.3×10^6 ha of wetlands have been destroyed in the past 60 years (Nivet and Frazier 2004; Eken *et al.* 2006). The most dramatic case is the Amik Lake in the 1960s, yet several other important wetlands have been lost recently, including Gavur, Emen, Suğla, Kestel, Söğütlü, Karagöl and Avlan lakes and the Aynaz swamps (Korkmaz 2008). The

draining and drying of these wetlands have had direct negative effects on biodiversity, with a few local extinctions. For instance, the African darter (*Anhinga rufa*) has not been seen in Turkey after Amik Lake dried up (Ünal and Canli 2019). More recently, the Turkish breeding population of the globally endangered white-headed duck (*Oxyura leucocephala*) dramatically decreased from 200–250 pairs to 82–125 pairs between 2001 and 2016, following the rapid drying of Central Anatolia lakes (Gürsoy-Ergen 2019; Özgencil and Uslu 2021).

In 1994, Turkey ratified the Ramsar Convention and designated its first five Ramsar Sites. Later in 2002, Turkey further elaborated its wetland conservation strategy with the ‘Regulation for Protection of the Wetlands’. A National Wetlands Commission (NWC) was established to plan the country’s rational use, management, and conservation of wetlands. In 2021, Turkey had designated 14 wetlands as Ramsar Sites and 56 wetlands were protected by national laws (General Directorate of Nature Conservation and National Parks 2020).

One of the Ramsar Sites in Turkey is the Gediz Delta (Fig. 1), located close to the city of İzmir on the Aegean Sea

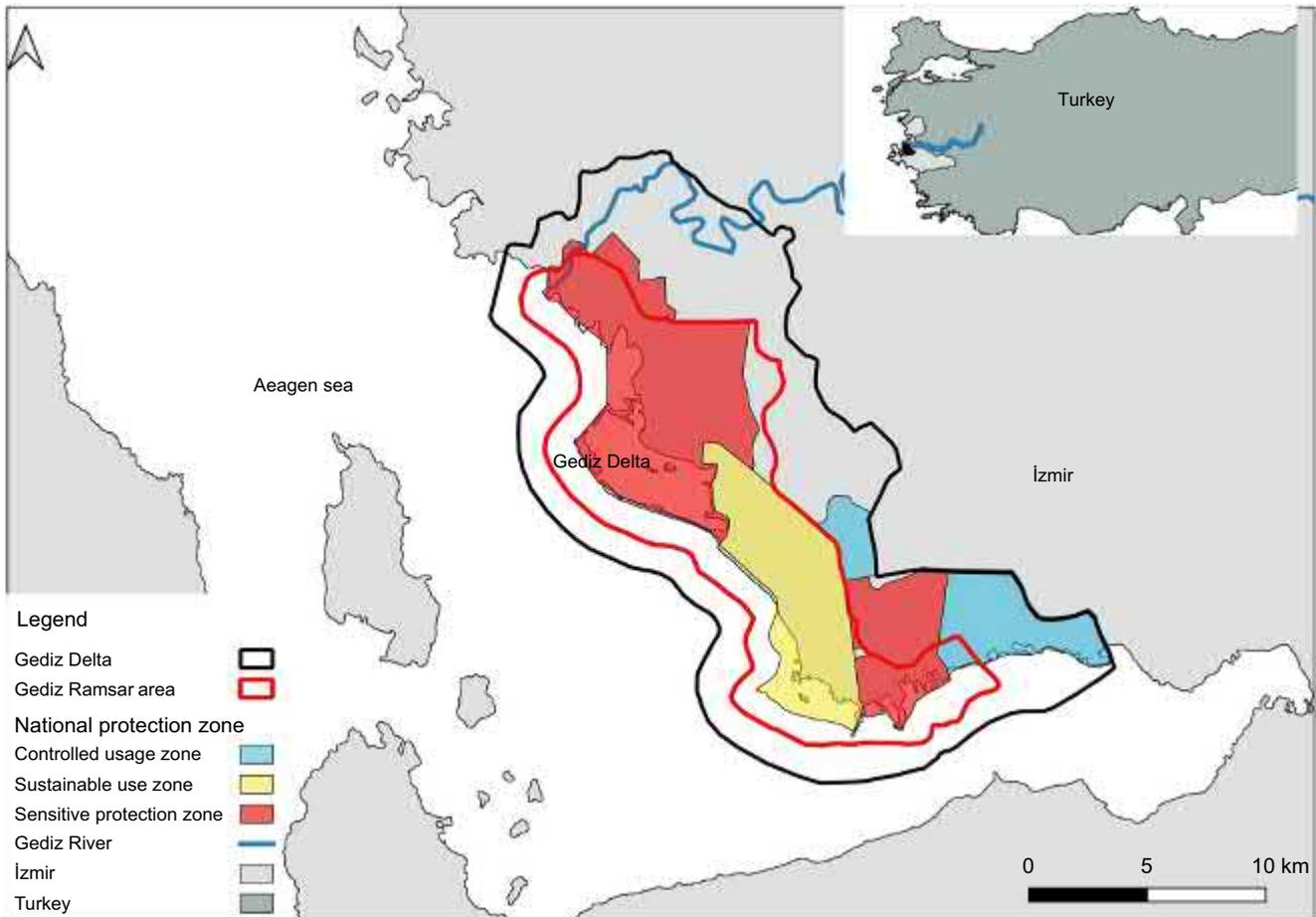


Fig. 1. Location of the Gediz Delta in Turkey.

coast (Gediz Delta Management Plan 2007). İzmir has a population of ~5 million people and the population continues to increase (TUIK website, see <https://www.tuik.gov.tr/>). Given its location on several migration pathways and its location between three continents, the Gediz Delta is extremely important for biodiversity (Yarar and Magnin 1997; Eken *et al.* 2006). Since 1985, the entire wetland habitat of the delta is a 'Natural Protected (SIT) Area' managed and surveyed by official rangers (Gediz Delta Management Plan 2007). In 1998, Gediz Delta was declared a 'Wetland of International Importance' by the Ramsar Convention because of the important role that its habitats provide for wetland bird species and its cultural and economic contributions to the local population (Gediz Delta Management Plan 2007; Ramsar Information Sheet on Ramsar Wetlands – 2006–2008 version, see <https://rsis.ramsar.org/>). The Delta has been severely affected by human activities for over a century and continues to be threatened despite the existing protection status (Ernoul *et al.* 2012; Avdan 2020). Urbanisation is the main driver of habitat transformation (Ernoul *et al.* 2012; Bolca *et al.* 2014; Avdan 2020); however, since the declaration of the Ramsar Site, no major land-use changes were observed within the Ramsar Site, but urbanisation has increased along the border of the Delta (Guelmami *et al.*, in press).

Like many Ramsar Sites around the world, the Gediz Delta has been studied sporadically over the years by both the scientific community and amateur birdwatchers, creating different origins and varieties of bird data sets. Hence, despite the availability of ornithological data for the Gediz Delta in scientific articles or databases, there are important temporal and species gaps that limit a comprehensive analysis of bird trends. For instance, the population counts have mainly focused on certain species of waterbirds (Sıki 1985; Eken 1997; Balkız 2006; Onmuş and Sıki 2011), in particular, the greater flamingo (*Phoenicopterus roseus*) and shorebirds, which all breed in the lagoon complex and the salt pans, but do not use the other ecosystems found in the Delta (e.g. farmland). Four inventories aimed at producing a bird atlas of the Gediz Delta have been conducted since the 1980s, providing good knowledge of the composition and distribution of the breeding species in all the ecosystems of the Delta, but with little information on species abundance (Sıki 1985; Eken 1997; Onmuş 2008; Arslan and Akyol 2020). So as to fill these gaps, we interviewed local expert ornithologists and reviewed ornithological literature to evaluate changes in bird populations over the past century. We then estimated the average bird abundance to assess long-term changes in bird community structure (Galewski and Devictor 2016).

Understanding and quantifying bird community changes over time can be useful to determine conservation and restoration priorities in many Ramsar Sites around the world. The sporadic and heterogenic data available for birds in the Gediz Delta are similar to those in many other

deltas in the Mediterranean basin; so, this methodology could offer the opportunity to better understand how the global change is affecting biodiversity, with a high potential for generalisation.

Materials and methods

Study site

Our study area encompassed the whole Gediz Delta, which extends over ~40 000 ha, constituting 20 400 ha of typical Mediterranean wetlands, including salt and freshwater marshes (5000 ha), salt pans (3300 ha) and four coastal lagoons (6300 ha; Gediz Delta Management Plan 2007; Fig. 1). The eastern part of the delta is heavily cultivated with annual crops. Natural wetlands, such as seasonal brackish and oligohaline marshes, are concentrated in the northern and southern parts of the delta and artificial wetlands are also concentrated inside the Ramsar area (salt pans and an artificial freshwater lake). The delta is mainly composed of flat areas at sea level and includes small hills up to 350 m above sea level in and around the wetlands. The site has a typical Mediterranean climate consisting of hot and dry summers and mild but windy winters, with an annual average temperature of 17.8°C (min. daily average 13.48°C and max. 22.6°C). The average annual rainfall is 695.4 mm (Turkish State Meteorological Service, see www.mgm.gov.tr, accessed 11 November 2020).

Expert-knowledge bird database

First, a review of scientific literature and ornithological reports dealing with the Gediz Delta was conducted to collect relevant data and to allow us to build a first list of bird species already observed in the delta (Sıki 1985, 1988; Kumerloeve 1986; Sıki and Öktem 1992; Eken 1997; Yarar and Magnin 1997; Sıki *et al.* 1998; Kirwan *et al.* 1999, 2010; Yaman 2001; Gediz Delta Management Plan 2007; Onmuş 2008; Onmuş *et al.* 2009; Onmuş and Sıki 2011; Gül 2014; Döndüren 2015; eBird, Cornell Lab of Ornithology, Ithaca, NY, USA, see <http://www.ebird.org>, accessed 12 August 2020; Türkiye'nin Anonim Kuşları, TRAKUS, see <http://www.trakus.org>, accessed 2 August 2021). Then, we constructed three independent databases for bird species observed in the Delta over three periods of (1) 1835–1979, (2) 1980–1999 and (3) 2000–2019 (Fig. 2). For each database, we distinguished between breeding and non-breeding species. The choice of periods was motivated by the temporal availability of ornithological data in the literature and by the period of activity of the ornithological experts in the Gediz Delta. The first database (1835–1979) included only presence data of each species, because there were no systematic bird counts taken prior to 1980 and because earlier ornithologists did not describe the level of abundance of the

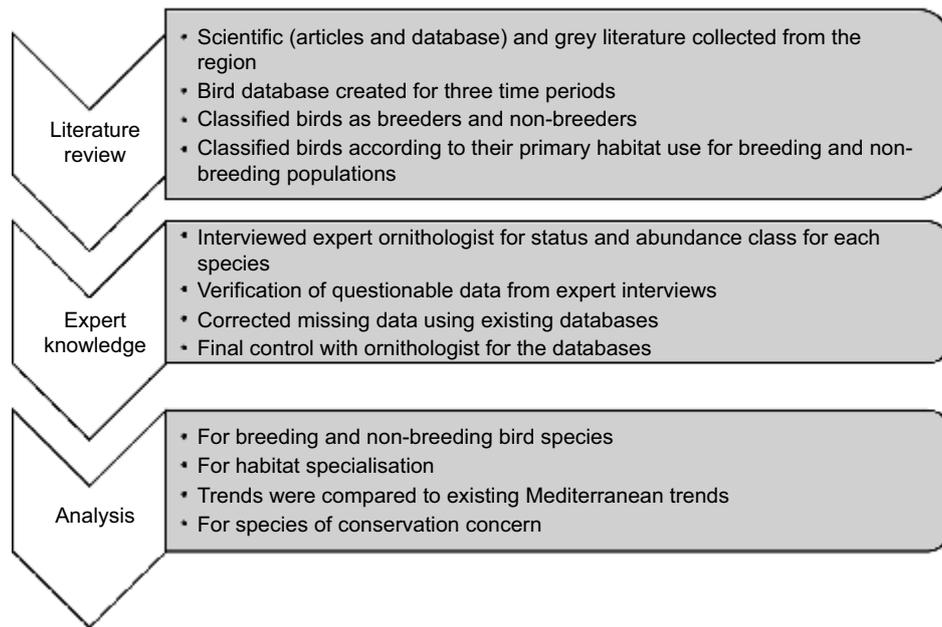


Fig. 2. Flow chart of methodology for developing the bird database and major steps to analyse the trends in the bird populations in the Gediz Delta, Turkey.

species they observed (Strickland 1836; von Gonzenbach 1859; Krüper 1869; Selous 1900; Ballance and Lee 1961; Siki 1985, 1988; Kumerloeve 1986). For the other two databases, we interviewed three local expert ornithologists who had a solid knowledge of the avifauna in the Delta (each had published articles and reports on the Delta, were active in scientific steering committees and were involved in the management planning for more than 10 years). The interviews were conducted with Prof. Mehmet Siki (Ornithologist specialist in Gediz Delta), Dr Güven Eken (ornithologist who has worked for Doğa Derneği) and Dr Ömer Döndüren (ornithologist, and the curator of the Birds Paradise Reserve located in Gediz Delta). We presented them a list of species occurring in the delta according to the literature and asked them to first assess the status of each species, as follows: R, resident for species observed throughout the year; S: species only present in spring–summer; W, wintering; M, passage migrants for birds only observed during migration and not breeding or wintering in the Gediz Delta; and V, vagrant species, not observed on an annual basis. Some species were assigned to several categories; for instance, resident and wintering if northern breeding populations join the resident population during winter months. We then asked the experts to evaluate the relative abundance using the following six semi-quantitative classes: 0 (absent); 1 (1–9 individuals); 2 (10–99); 3 (100–999); 4 (1000–9999); 5 (more than 10 000). This was undertaken for both breeding and non-breeding populations, following a methodology developed for the Camargue in southern France, a wetland that is comparable in size and bird community composition (Galewski and Devictor 2016). As the abundance of many

bird species varied over the course of the year, the experts gave the maximum abundance, i.e. the maximum observed in an average year for each period. Last, the experts were asked to correct and validate the databases as a final step, looking specifically at the abundance change over time.

At the first stage of analysis, we compared the information to current trends in the Mediterranean basin. At this time, we observed different trends between the Gediz Delta and the Mediterranean basin for 56 species. For these species, we conducted a second interview with the experts to validate the information (status and abundance). All of the species information was validated by experts, except for 18 species. For these species, we relied on mid-winter waterbird counts (available since 1997), literature and eBird records (such as abundance ranges or observed date) to complete the status. Vagrant status was given for 15 of 18 species. In all, 2 of the 18 species were reevaluated for abundance classes (*A. albifrons* and *P. porzana*), and one for status (*C. spinus*). For the 2000–2019 database, we added the trend in abundance since the 1980–1999 period, as follows: (–1) ‘decrease’ | (0) ‘stable’ | (1) ‘increase’. Evaluation of the trend scores was made using the following assessment. We first checked the breeding status (B, breeding; N, not breeding) and determined any changes from earlier periods. If the species stopped breeding, then the trend was set as decreasing (–1), and if a species started to breed in the site, then the trend was set as increasing (1). If there was no change in the breeding status, we ranked the population activity status (R, M, S, W, V) of each species in function of the relative length of time the bird spent on site, and evaluated the population status changes across $R > S = W > M > V$. If

there was a difference between t and $t + 1$ time according to this order, we then scored the trend according to the change. For example, if in time t the species was a resident species, and at time $t + 1$ the species was recorded only as wintering but not breeding any more, we set the population trend to decreasing. If there was no change in the occurrence status of the bird, we checked the population size score. If the score increased, we considered that the trend increased. If the score decreased, the trend was set to decreasing, or if no change occurred, the population was set to stable. Finally, we indicated the main habitat used by each species by using six categories corresponding to the following habitat classes: 'Agricultural and Grassland', 'Forest', 'Inland Wetlands', 'Marine and Coastal' (including lagoons, salt pans, beaches and open sea), 'Mediterranean Habitats' (scrublands and bushy vegetation) and 'Generalist' (for bird species using more than one of these habitat types; [Guelmami et al., in press](#)). The assignment of bird species to each habitat was undertaken following the bird habitat classification provided in the second EBBA Atlas ([Keller et al. 2020](#)), with the help of local bird experts for migratory or wintering populations. This was undertaken separately for breeding and non-breeding seasons, because many bird species show different habitat preferences over the course of a year. To assess changes according to the regional conservation value of the Gediz Delta bird community, we also reported, for each species, the conservation priority status given by BirdLife through the Species of European Concern list (SPEC; [BirdLife International 2017](#)) and through the Annex I of the European Union Bird Directive (ec.europa.eu). We chose to use these lists because they provide important information on the conservation value of bird species at the European scale. Although Turkey is not part of the European Union, many of the bird species found in the European Union use the Gediz Delta as a migratory route or stop over ground and there are exchanges between populations breeding in the Gediz Delta and those in EU wetlands (for instance, for the greater flamingo and the Dalmatian pelican). The Annex I of the EU bird directive is a legal document listing species that have required conservation action since 1979 (with some updates with new species). Species that are not listed in the Annex I are usually less targeted by conservation measures or can be legally exploited. The SPEC list is not a legal document but a scientific conservation list that is constantly being updated, showing which species need conservation action in Europe. A national Red List of Threatened bird species was not available for Turkey and could not be used in this study.

Average abundance (AAB) of bird communities

For each bird category (defined as the species pool responding to a given criteria of habitat use or conservation status), we calculated the average abundance (AAB) in bird communities

to estimate the average abundance of the species of that community ([Galewski and Devictor 2016](#)). AAB uses the weighted mean of the abundance of a species to characterise the average abundance of a species in the overall bird community ([Galewski and Devictor 2016](#)), as follows

$$\text{AAB} = \sum a_i \div \sum i$$

where 'a' is the abundance classes (defined by five population size categories as described above) of a species 'i'. AAB scores compared the communities of both breeding and non-breeding birds in the Delta. Then, AAB was calculated for species listed in SPEC and Annex I in the Bird Directive for the two time periods, to compare trends in species in function of their regional conservation value (1980–1999 and 2000–2019; Supplementary Table S1). Vagrant species were not included but are mentioned if their status has changed (such as if they started to occur more regularly; [Fig. 2](#)). AAB was calculated for each period and each habitat (see above for the habitat categories). All analyses were conducted using R software (ver. 3.6.3, R Foundation for Statistical Computing, Vienna, Austria, see <https://www.r-project.org/>) with the package 'dplyr' (ver. 1.1.10, H. Wickham, R. François, L. Henry, K. Müller and RStudio, see <https://CRAN.R-project.org/package=dplyr>).

Results

Expert knowledge database

Extinct and new species in the long term

Overall, bird trends show an increase in the number of bird species observed over the three time periods. In all, 299 species were recorded since 1835, including 139 species between 1835 and 1979; 244 between 1980 and 2000 and 288 from 2000 until 2019 (Table S1). Approximately 22% of all species (66 of 299 species) were recorded as vagrant only. This is, for instance, the case of the common eider (*Somateria mollissima*), which usually spends winter at higher latitudes but was observed in the Gediz Delta for the first time in 2019 (eBird, see <http://www.ebird.org>). Of the 36 species recorded for the first time between 2000 and 2019, only eight now occur regularly, usually in small numbers; five are winter residents (lesser flamingo, *Phoeniconaias minor*; whooper swan, *Cygnus cygnus*; greater spotted eagle, *Clanga clanga*; bar-tailed godwit, *Limosa lapponica*; rook, *Corvus frugilegus*), one is a non-breeding summer resident (Scopoli's shearwater, *Calonectris diomedea*), one is a passage migrant only (citrine wagtail, *Motacilla citreola*), and one is a permanent resident (ring-necked parakeet, *Psittacula krameri*). The ring-necked parakeet is an invasive exotic species, well established in İzmir and recorded in the south of the Gediz Delta close to the city.

The historical records indicate the loss of the following four species: black francolin (*Francolinus francolinus*; Strickland 1836), black-bellied sandgrouse (*Pterocles orientalis*; von Gonzenbach 1859), Egyptian vulture (*Neophron percnopterus*) and great bustard (*Otis tarda*; von Gonzenbach 1859; Krüper 1869). The black francolin and great bustard were frequently observed in the İzmir Plains (Strickland 1836) and they were likely to be present there as resident species. Evidence has shown that three black francolin eggs were taken near İzmir on 10 May 1899 (Kirwan *et al.* 2010), and a breeding population of great bustard at Marmara Lake (Manisa) was observed in the Aegean region, within 100 km of the Gediz Delta (Karakas and Akarsu 2009). The status of the Egyptian vulture is less clear, but it was observed in an area suitable for breeding in Bornova, İzmir, in 1899, at a time where the species was much more common in the Mediterranean basin (Selous 1900). The black-bellied sandgrouse was noted in the İzmir list only by Strickland (1836), and it could have been either a resident or only wintering in the Delta. In addition, the white-throated kingfisher (*Halcyon smyrnensis*) was also a resident bird species in the Delta from 1720 (first recorded by W. Sherard, reported in Kirwan *et al.* 2010) to 2000, but is now considered locally extinct. In our study, we considered this species to be vagrant as it was observed in the Delta for the last time in 2002 (eBird, see <http://www.ebird.org>). Pied kingfisher (*Ceryle rudis*) was recorded by Selous (1900) and was observed one time in 1987 by Mehmet Siki (Kirwan *et al.* 2010), but its past status remains unclear.

Breeding species

In total, 95 bird species were recorded as breeders in the 1980–1999 time period, and 103 species were breeding in 2000–2019. In total, 115 species were recorded as breeding species in the 1980–2019 time period in the Delta. Twelve species recorded as breeders in the Delta between 1980 and 1999 have not been breeding since 2000, including the Eurasian spoonbill (*Platalea leucorodia*) and the black-crowned night heron (*Nycticorax nycticorax*). By contrast, 20 bird species started to breed in the Delta after 2000 (Fig. 3, Table S1). A majority of these new breeding species were ‘agricultural and grassland’ specialists. ‘Generalist’ species ranked second in the number of breeders, followed by ‘wetland’ species. The least common breeding species were ‘forest’ species (Fig. 4).

Non-breeding species

In total, 227 species were regularly observed as non-breeders in the Delta in the 1980–1999 period and 233 in the 2000–2019 period (Table S1). In total, 30% of those species are resident, 50% are summer non-breeding or wintering species and 17% are passage migrants in the Delta. Five species were regularly seen between 1980 and 1999, but were not observed regularly in the 2000–2019 time period, including greylag goose (*Anser anser*), white-headed duck (*Oxyura leucocephala*), Eurasian eagle owl (*Bubo bubo*), white-throated kingfisher (*Halcyon smyrnensis*) and rock bunting (*Emberiza cia*). By contrast, 11 new species were regularly observed in the 2000–2019 time period,

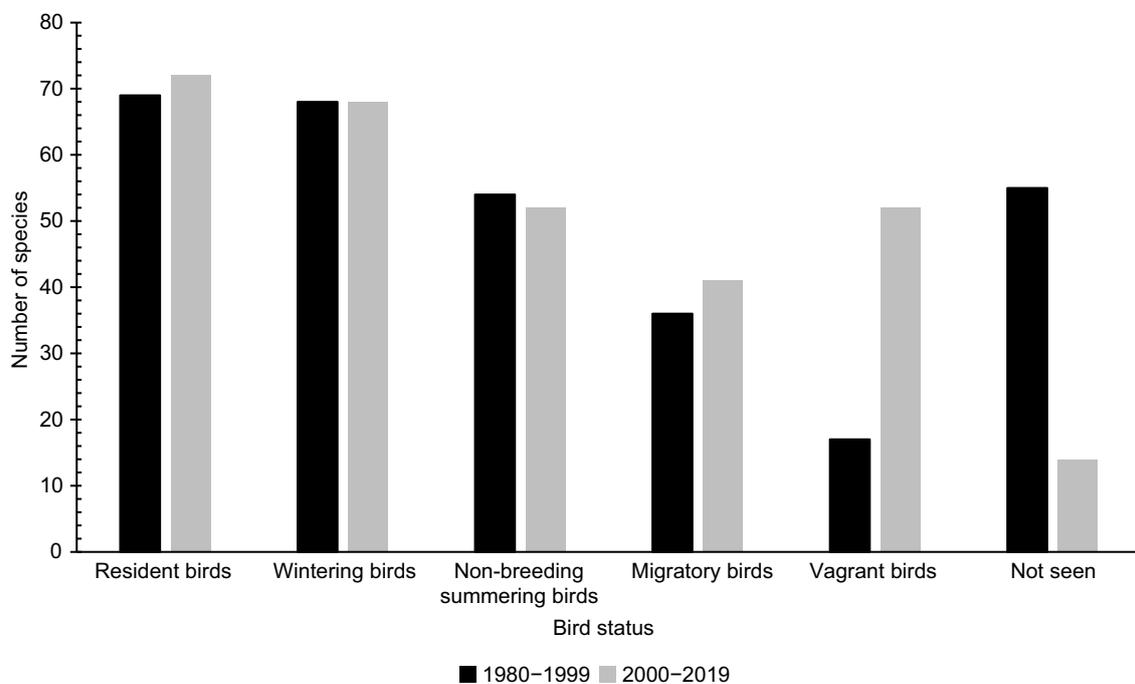


Fig. 3. Number of species recorded in the Gediz Delta, Turkey, in two different time periods (1980–1999 and 2000–2019; $n = 299$).

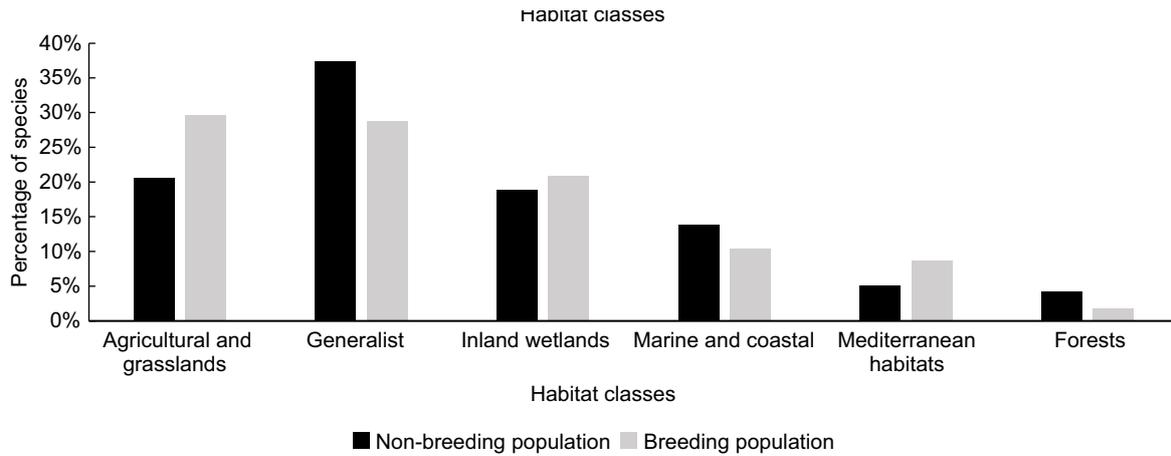


Fig. 4. Percentage of variation of bird species depending on habitat classes in the regular observed species ($n = 238$ species) and breeding species ($n = 115$ species) in the Gediz Delta, Turkey. On the y-axis, change for the percentage of species in each habitat.

including the mute swan (*Cygnus olor*), citrine wagtail (*Motacilla citreola*), and rook (*Corvus frugilegus*; Fig. 3). ‘Generalist’ species ranked first in the number of non-breeding species, followed by ‘agricultural and grasslands’ and ‘wetland’ species (Fig. 4).

Species trends

The total score for the 238 species observed in both species groups showed that 27% of species decreased in abundance between the two time periods, 40% were stable, and 33% increased. When assessing species trends in function of their main habitat type, we found that a majority of ‘agricultural

and grassland’ birds have declined (40.8%), whereas 48.5% of ‘marine and coastal’ and 40.0% of ‘inland wetland’ birds have increased (Fig. 5).

Changes in AAB

The AAB of breeding species (115 species) has not changed between the two time periods (1980–1999 and 2000–2019), suggesting an overall stability in community abundance in breeding birds (Fig. 6). However, this trend varies between the two periods according to the habitat specialisation of the bird community. There is an increase in the AAB of birds breeding in ‘marine and coastal’ habitats (+64.7%)

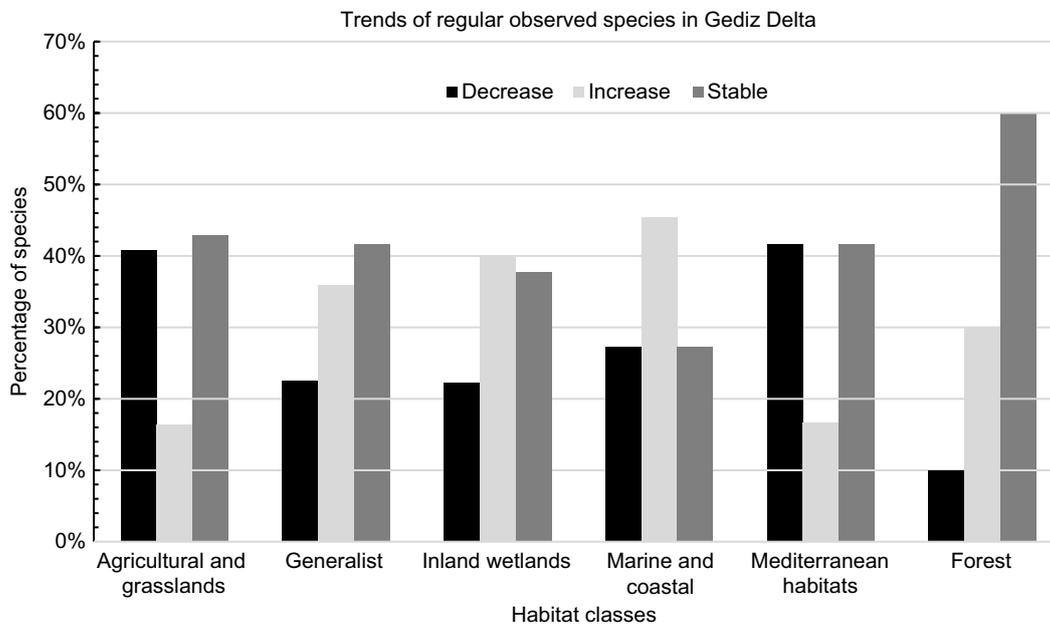


Fig. 5. Trends (decrease, increase or stability) of bird species ($n = 238$) in the Gediz Delta from 1980 to 2019, according to their habitat specialisation.

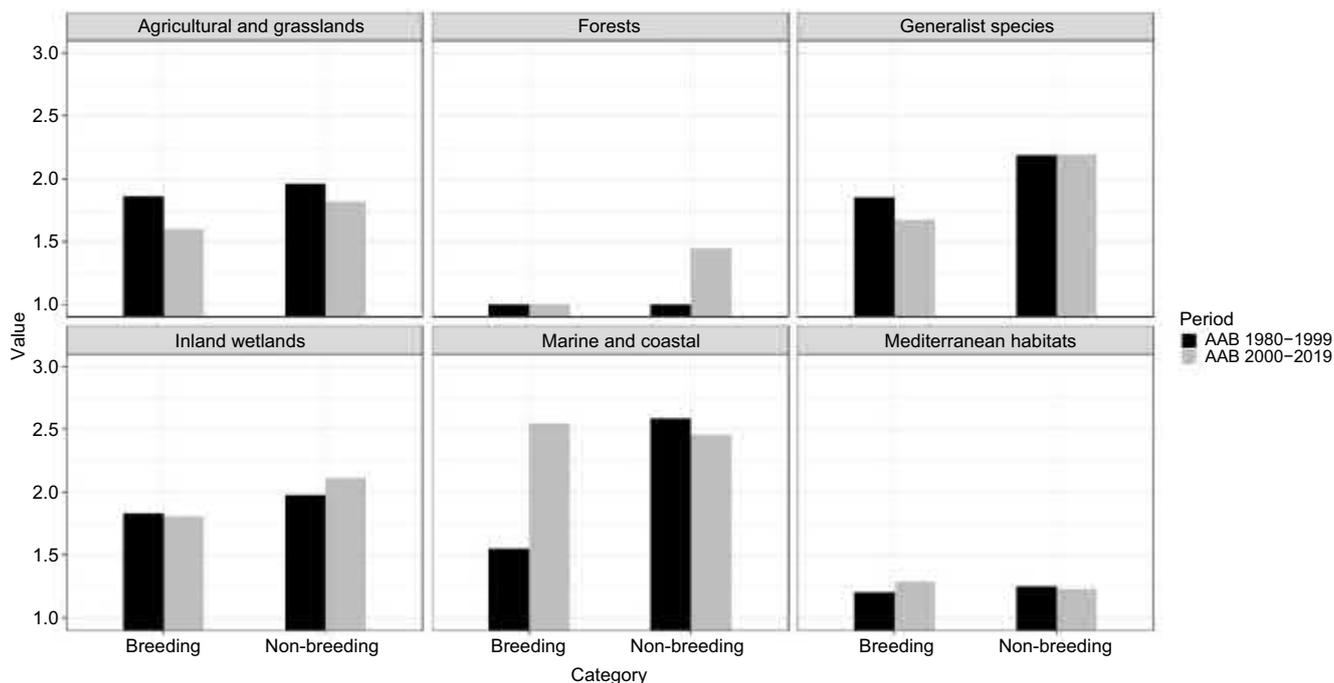


Fig. 6. Change in the average abundance (AAB) in each habitat in breeding and non-breeding birds over time in the Gediz Delta, Turkey, from 1980–1999 to the 2000–2019 time period. On the x-axis, change for the AAB scores of habitats.

and, to a lesser extent, those breeding in the ‘Mediterranean’ habitats (+7.1%; Fig. 5, Table 1). On the contrary, breeding birds in ‘agricultural and grassland’ (–14%) and ‘Generalist’ species (–9.7%) showed a decreasing AAB value between the two time periods. The AAB of ‘inland wetland’ species is fairly stable between the two time periods (–1.2%). For non-breeding bird populations (238 species), there is almost no change in general AAB between 1980–1999 and 2000–2019 (+0.3%). When looking at AAB per habitat specialisation, we observed limited variations over time compared with breeding bird populations. AAB of birds using ‘Mediterranean’ habitats or ‘generalists’ were stable between the two time periods. AAB slightly decreased for the ‘agricultural and grassland’ species (–7%), and ‘marine and coastal species’ (–5.1%). However, there was a slight increase in the AAB of ‘inland wetland’ species (+7%) and more marked for ‘Forest’ species (+44%), even if the pool of species is very limited for this last category (10 species; Fig. 6, Table 1).

Conservation status

Most of the breeding species are not listed in Annex I (39 species listed of 115 breeding species under the Annex I) and SPEC (47 of them listed under SPEC). Of the 238 non-breeding species, 91 were listed as SPEC and 88 were listed in Annex I (Table 2). In the breeding-bird community, species listed in Annex I have increased in AAB (27.17%). The AAB index of the species not listed in Annex I decreased slightly (–8.44%; Fig. 7). The non-breeding bird population species

listed in Annex I slightly increased (2.2%), whereas there was almost no change (0.18%) for the species not listed in the Annex I (Fig. 7). The species listed in SPEC do not show much change in AAB for either non-breeding nor breeding species populations. The species not listed in the SPEC list (lower conservation value) slightly decreased in both breeding and non-breeding populations (Fig. 7).

Discussion

By combining historical records and expert knowledge, we have shown different trends depending on bird community and habitat preference in the Gediz Delta over the past century. For breeding bird species, there were decreasing trends in ‘agricultural and grassland’ species, whereas there were important increases in ‘marine and coastal’ bird species. The observed changes in the breeding bird communities could be related with the land-use and land-cover changes that happened in the Delta. Previous studies have shown significant changes in the study area, with natural dry-lands and agricultural lands being converted to urban areas, and most of the natural wetlands having been converted into artificial wetlands, especially the brackish waters to salt pans (Ernoul *et al.* 2012; Bolca *et al.* 2014; Guelmami *et al.*, in press). These changes are most likely to have favoured ‘marine and coastal’ bird species, while penalising ‘agricultural and grassland’ species. Changes of the AAB index of the bird community coincides with the previous

Table 1. Summary of observed changes in the average abundance (AAB), for each bird community, possible factors driving the change and references for land use changes in the Gediz Delta, Turkey.

Bird community	Changes in bird abundance	Possible factors driving these changes	References for changes in LULC
Marine and coastal species	<ul style="list-style-type: none"> • AAB breeding has increased (+64%) 	<ul style="list-style-type: none"> • Positive effects of expansion of Salinas surface by 62% • Coastal habitats are in protected areas • Special protection efforts such as construction of flamingo islands 	Balkiz <i>et al.</i> (2009); Bolca <i>et al.</i> (2014); Guelmami <i>et al.</i> (in press)
Inland wetlands species	<ul style="list-style-type: none"> • AAB breeding is almost stable • AAB non-breeding species and total richness increased 	<ul style="list-style-type: none"> • Artificial freshwater supply • The biggest freshwater lake is in protected area 	Gediz Delta Management Plan (2007); Gediz Delta Revised Management Plan (2018)
Agricultural and grassland Species	<ul style="list-style-type: none"> • AAB breeding and non-breeding decreased 	<ul style="list-style-type: none"> • Many grassland habitats disappeared by urbanisation • Intensive agricultural practices increased 	Efe (2007); Bolca <i>et al.</i> (2014); Guelmami <i>et al.</i> (in press)
Mediterranean habitat	<ul style="list-style-type: none"> • AAB of breeding increased • AAB of non-breeding almost stable 	<ul style="list-style-type: none"> • Semi-natural habitats seem to be declining 	Ernoul <i>et al.</i> (2012); Bolca <i>et al.</i> (2014); Guelmami <i>et al.</i> (in press)
Forest species	<ul style="list-style-type: none"> • AAB of breeding species is stable • AAB non-breeding species increased 	<ul style="list-style-type: none"> • Increasing plantations in recent periods • Less observation 	Ernoul <i>et al.</i> (2012); Bolca <i>et al.</i> (2014); Guelmami <i>et al.</i> (in press)
Generalist species	<ul style="list-style-type: none"> • AAB breeding decreased, but number of species has increased • AAB non-breeding is stable 	<ul style="list-style-type: none"> • The expansion of urban settlements • Increasing plantations 	Ernoul <i>et al.</i> (2012); Bolca <i>et al.</i> (2014); Guelmami <i>et al.</i> (in press)

Table 2. Number of species, percentage listed in lists of species with conservation concern (SPEC and Annex I list) in the Gediz Delta, Turkey.

Item	Number of species	SPEC list (%)	Not listed-SPEC list (%)	Annex I list (%)	Not listed-Annex I list (%)
Breeding species					
Agricultural and grasslands	34	32.4	67.6	35.3	64.7
Forests	2	50.0	50.0	50.0	50.0
Generalist	33	72.7	27.3	18.2	81.8
Inland wetlands	24	66.7	33.3	41.7	58.3
Marine and coastal	12	66.7	33.3	75.0	25.0
Mediterranean habitats	10	80.0	25.0	10.0	90.0
Total	115	59.1	33.9	33.9	66.1
Non-breeding species					
Agricultural and grasslands	49	65.3	34.7	40.8	59.2
Forests	10	20.0	80.0	40.0	60.0
Generalist	89	27.0	73.0	29.2	70.8
Inland wetlands	45	40.0	60.0	40.0	60.0
Marine and coastal	33	36.4	63.6	51.5	48.5
Mediterranean habitats	12	25.0	75.0	25.0	75.0
Total	238	38.2	61.8	37.0	63.0

trends identified by Onmuş *et al.* (2009, 2011), with avifauna responding to local land-use changes in the Gediz Delta. Similar land-use and land-cover trends are found around the Mediterranean basin (Mediterranean Wetland Observatory 2014) and greatly affect the biodiversity living in and around the wetlands (Galewski *et al.* 2011). However, species that have been protected at the European

level for a long time and have been targeted by conservation policies (species of Bird directive, Annex I) also increased in abundance in the Gediz Delta. These results suggest that conservation actions in one country can have a positive effect elsewhere in the species' range. Conversely, the breeding species not listed in Annex I decreased in abundance on average, suggesting that non-

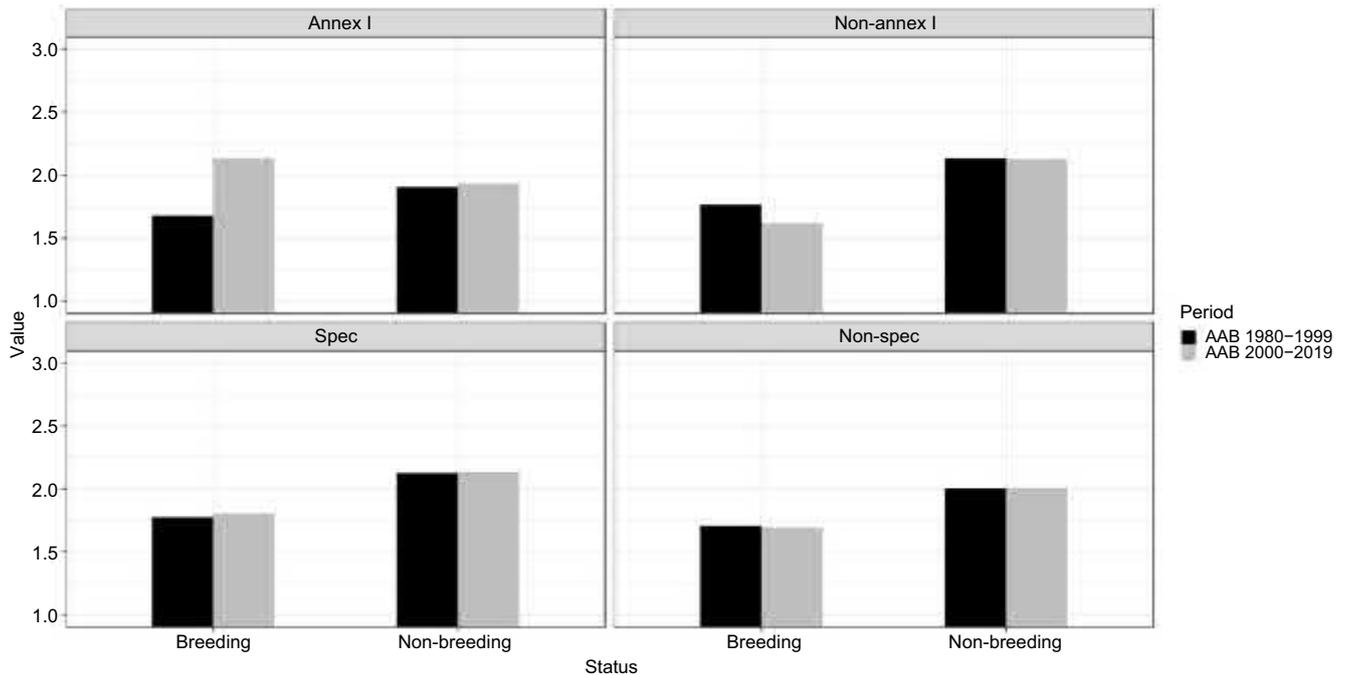


Fig. 7. Change in the average abundance (AAB) of (a) breeding and (b) non-breeding species in relation to the listing of species regarding their conservation status in the Gediz Delta, Turkey. On the y-axis, changes for the AAB scores of conservation groups.

protected species may also have declined owing to less conservation effort on a broader scale. For instance, this is the case of the Eurasian skylark and the house sparrow, which declined in Gediz Delta as well as in large parts of Europe. This increase in species found in the Annex I list confirms the efficiency of the protection status (Koschová *et al.* 2018) and suggests that similar regulations should be applied to other species with unfavourable conservation status. This result is similar to what can be observed in many other places in Europe where formerly common species, and thus not targeted by conservation efforts, have declined (Inger *et al.* 2015). In this context, we recommend that conservation policies similar to those in Europe be extended to Turkey for the species, without species conservation action plans.

Bird communities can provide information about the changes in the biodiversity status of socio-ecosystems (Galewski and Devictor 2016). The average abundance of breeding bird species in ‘coastal and marine’ areas increased in the Gediz Delta during the same period as the saltpans in the Delta expanded (Ernoult *et al.* 2012; Bolca *et al.* 2014). We suggest that the land-use change from natural wetland areas to artificial (saltpans) but protected wetlands has positively affected specialist birds of ‘coastal and marine’ habitats; the artificial wetland (saltpans) area increased ~62% (from ~2005 ha in 1984 to 3257 ha in 2020; Bolca *et al.* 2014; Guelmami *et al.*, in press). As in other wetlands around the world, this kind of land-use change (such as increases in saltpans) has led to an increase in the number of species specific to these habitats

(Sripanomyom *et al.* 2011; Márquez-Ferrando *et al.* 2014). However, these highly saline habitats are beneficial only to a very small number of species (Sebastián-González and Green 2016). Several management measures have enhanced these trends, such as the building of artificial islands for the reproduction of flamingos (Balkiz *et al.* 2007), with an increase in the breeding population size by more than 40 times between 1980 and 2019, or nesting platforms for other species such as gulls and terns. The expansion of saltpans seems to have also positively affected non-breeding populations (more species have increased than decreased between the two time periods), even if the establishment of new species in very low numbers has led to a small decrease of AAB in non-breeding ‘marine and coastal’ species.

Despite almost no variation in AAB for specialist species breeding in ‘Inland wetland’ habitats, it is important to highlight that there was an increase in the total number of breeding species in this habitat, with six new species and three extinct species as breeders between the two most recent time periods. These new breeders, such as the mute swan (*Cygnus olor*) and the little bittern (*Ixobrychus minutus*), are mainly linked to reedbeds. These colonists could be attributed to conservation efforts of the wetland habitats in the Delta (such as pumping freshwater into Gediz Delta). By contrast, some species were negatively affected by the variable water level in the reedbeds, such as Eurasian spoonbill (*Platalea leucorodia*) and the black-crowned night heron (*Nycticorax nycticorax*). It is important to note that the reedbeds in the Delta were almost completely dry in the

early 2000s when the National Park administration then decided to pump water to protect the reeds and freshwater habitats (Ernoul *et al.* 2012; Bolca *et al.* 2014; Avdan 2020). Given that these habitats are very dependent on continual freshwater supplies, the sustainability of these habitats requires continued pumping coming from the irrigation channels flowing from the Gediz River (Gediz Delta Management Plan 2007). Therefore, the population size of 'inland wetland' birds may have remained small because of the limited surface area that freshwater marshes represent in the delta (Siki 2020). Likewise, the extinction of Smyrna kingfishers that build their nests in the soft bed of rivers is probably the consequence of the re-alignment and embanking of the Gediz River (land-use change; Eken 1997).

Our study also highlighted the possible impact of agricultural practices and intensification on certain species associated with 'agricultural and grassland' ecosystems. Here, we observed a decrease in the numbers and abundance index in breeding species, with several formerly common species that recently became scarcer (e.g. Calandra lark, greater short-toed lark, corn bunting, Spanish sparrow) or even recently stopped breeding (Eurasian skylark). This result is similar to trends observed on bird populations after agricultural intensification (Gil-Tena *et al.* 2015; Katayama *et al.* 2015; Alderson and Sander 2021). One reason for the local decline of breeding birds in agricultural and grassland habitats is that the avifauna linked to semi-natural grassland environments have undergone significant changes over the past century, which could be linked to a change in the vegetative structure caused by reduced grazing pressure (Mérö *et al.* 2015) or conversion of grasslands into agricultural areas (Bolca *et al.* 2014). Historic literature suggests that the cultivation of grasslands is one of the major drivers of change in the Gediz Delta bird community in the long term. Some steppe species were present in the Delta over the past two centuries (some of which remain today, e.g. Calandra lark), but others are virtually extinct (e.g. eastern imperial eagle, great bustard, black-bellied sandgrouse; Strickland 1836; von Gonzenbach 1859; Selous 1900; Kirwan *et al.* 2010). This change could largely be attributed to the conversion of large pastoral areas into agricultural fields before 1980 (agricultural land increased 13% between 1963 and 2010; Bolca *et al.* 2014). Moreover, agricultural practices have evolved in the Delta, with drainage and reclamation methods to increase agricultural production (Efe 2007; Bolca *et al.* 2014). More recently, the urbanisation pressure of the growing city of İzmir and the plantation of *Eucalyptus* trees also may have reduced suitable breeding habitats for these species (Robledano *et al.* 2010; Avdan 2020). Before the 1990s, there were species linked to semi-natural grasslands such as the stone curlew (*Burhinus oedicnemus*), calandra lark (*Melanocorypha calandra*), short-toed lark (*Calandrella brachydactyla*), and isabelline wheatear (*Oenanthe isabellina*) in the southern part of the Delta, but after the 2000s, these species no

longer bred in that area and were replaced by birds nesting in wooded areas such as the great tit (*Parus major*), blue tit (*Cyanistes caeruleus*) and golden oriole (*Oriolus oriolus*).

In the Gediz Delta, the 'Generalist' and 'Mediterranean habitat' categories combine species with diverse ecological requirements. These differences might explain diverging trends, with an overall abundance increase in breeding species, showing a strong attraction for highly anthropised habitats such as urban areas (e.g. the 'generalists' Eurasian collared dove or hooded crow and the 'Mediterranean habitats' red-rumped swallow) or plantations of exotic trees (e.g. the 'generalists' great tit or common chaffinch), whereas species more linked to semi-natural habitats seem to be declining (e.g. *Sylvia* spp., western rock nuthatch). But, again, the expansion of urban settlements (Ernoul *et al.* 2012; Bolca *et al.* 2014; Avdan 2020) within and on the southern margin of the Delta might drive these opposite trends. Also, the cumulative effects of both increasing plantations in recent periods and less observation or underreporting of passerines in the first period owing to a greater interest in waterbirds could also be a possible explanation for the increase in AAB of non-breeding 'forest' birds.

With the poorer trends of agricultural, grassland and semi-natural species in the Delta, the necessity of conducting more detailed research on these species has emerged. The Delta is renowned for its waterbird populations, with breeding, wintering and migrating numbers exceeding the criteria of international importance for several species (e.g. greater flamingo, Dalmatian pelican, pygmy cormorant, pied avocet, little stint). It is highly likely that the protection given to many coastal species both at national and international levels (as Ramsar Site) has played a key role in improving the local conservation status of wetland birds. However, the majority of breeding and non-breeding species in the Delta whose conservation is currently considered to be of European concern are species associated with terrestrial habitats, particularly agricultural and grassland environments. Most often, conservation activities do not include these non-targeted farmland species (Chamberlain and Crick 1999; De Laet and Summers-Smith 2007; Galewski and Devictor 2016). Therefore, our results argue in favour of extending biodiversity conservation measures to the Delta's terrestrial ecosystems, which have so far been largely forgotten by conservation policies. The same pattern has been observed in the Camargue, another large Mediterranean delta, where similar contrasting trends were found between birds breeding in wetlands (long-term increase) and farmland birds (long-term decline; Galewski and Devictor, 2016).

The low number of bird species recorded in the early periods could be explained by the low number of observers, since the Delta was not systematically studied by ornithologists until the 1980s (Özesmi and Per 2006). For this reason, there is certainly a lower number of bird species detected and recorded in the early periods because of lower observation pressures. Additionally, the experts' opinions

might also be biased because their studies mainly concentrate on the Ramsar part of the Delta (within the nationally protected site) and do not include all the ecosystems encountered in the Delta. It should be noted that most agricultural and grassland habitats are located outside the reserve, which could cause the number of birds to be underestimated. We also acknowledge that there could be some limitations in precision concerning abundances because there could be bias based on observers' subjectivity. The use of historical reports and grey literature may have reduced these biases. Another limitation of this study is that we attempted to link changes in the bird community with bird habitat specialisation, using land-use and land-cover changes in the Gediz Delta. However, other drivers of community changes such as climate change or regional conservation efforts happen at a much larger geographical scale or local's behavioural changes (such as restriction for hunting by laws) also have affect Gediz bird populations. In this sense, it is better to focus on changes in breeding populations than in the non-breeding bird populations because they have stricter requirements for particular habitats and are more sensitive to habitat modifications (Greenwood 2003), as was confirmed in our study where we found more changes in the breeding bird community than in the non-breeding community.

This study clearly demonstrated the importance of land and water management planning to mitigate adverse effects of threats, not only for species of conservation concern, but also for common species and habitats in the Delta. It demonstrated the importance of conserving 'agricultural and grassland' habitats to reverse the negative trends and prevent the extinction of 'agricultural and grassland' bird species in the Delta. We also showed the importance of freshwater supplies (which is continued, pumping to reedbeds) to the 'inland wetland' habitats for maintaining the habitats and their associated species (Sıki 2020; Arslan *et al.* 2021; Guelmami *et al.*, in press). Therefore, we recommend that conservation actions should not only focus on fragile coastal wetland habitats, but should be oriented towards other natural terrestrial and freshwater habitats in the inner parts of the Delta, creating a mosaic of habitats that is beneficial for biodiversity (Galewski and Devictor 2016). This management should especially consider all natural landscape patches in agricultural and urban landscapes to effectively conserve regional biodiversity in terms of the rich taxonomic elements they contain (Vallejo *et al.* 2009; Newbold *et al.* 2020).

Our study showed that a combination of literature review, expert interviews and freely accessible bird data can be useful to understand bird trends and their link to habitat dynamics. The study highlighted that major land-use and land-cover change affect bird diversity; some transformations (such as the conversion of natural wetlands to artificial wetlands) may be more favourable for some marine and coastal birds. Other factors that are not visually apparent (changes in

agricultural practices, such as using herbicides or pesticides) could also have negative repercussions. This method effectively evaluates how biodiversity is changing, allows for the assessment of the efficiency of protected areas, and prioritises new conservation issues without being limited to the long-term monitoring results. This kind of information is important to promote the conservation of sensitive wetland habitats and could be generalised to many other sensitive ecosystems.

Supplementary material

Supplementary material is available [online](#).

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