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Long-term population trends of bird communities in artificially-protected wetlands of Northern Italy

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Abstract - Artificial wetlands have become a common conservation approach to contrast the decline of biodiversity globally, as a result of the ongoing loss and fragmentation of natural habitats. Assessments on the trend of the avian biodiversity in artificial wetlands are essential to understand their conservation value. This study aims to analyse temporal changes in the abundance of bird guilds and species in small artificial wetlands in Northern Italy. We surveyed bird populations over the 2005-2019 period from three adjacent wetlands, and examined temporal trends of species as both single species and grouped in guilds. We found the water systems analysed supported a high diversity of species. Overall, we found Swans and Geese, Cormorants, Raptors and Large wading birds had an increasing trend between 2005 and 2019, while Gulls and Terns were stable, Ducks, Rails and Cranes, and Grebes and Divers were uncertain, and Shorebirds decreased. Species-specific trends were revealed: *Circus cyaneus* (+13.40%) and *Falco vespertinus* (+21.32%) increased, while *Calidris pugnax* decreased (-7.91%) and *Aythya nyroca* was uncertain (+6.30%). Furthermore, dominant species had mainly a stable abundance (e.g. *Larus ridibundus* and *Anas platyrhynchos*), while *Anas crecca* increased (+2.97%), *Vanellus vanellus* decreased (-3.65%), and *Fulica atra* had an uncertain trend. We described these local systems as of vital importance to sustain the local and regional avian biodiversity, also urging to ensure national and international functional connectivity between natural and artificial systems.

Keywords: waterbirds, temporal trend, artificial wetland, Po Plain, conservation

INTRODUCTION

Wetlands represent important habitats that sustain a great variety of vertebrate and invertebrate assemblages through their high productivity (Kingsford et al. 2016).These areas have been sharply decreasing globally at an alarming rate due to land modifications (Gibbs 1993, Panuccio et al. 2017, Gòmez-Baggethun et al. 2019) with a consequent erosion of biodiversity (Inger et al. 2014, Morelli et al. 2020). Europe shows one of the most serious situations with respect to wetland loss, having already lost up to 45% of its wetlands (Verhoeven 2014). For instance, the Po Plain (Northern Italy), which comprises most of the Italian wetlands, is characterized almost entirely by an anthropized environment, with few areas still natural, more frequently semi-natural (Maiorano et al. 2007). Within this context, in the Modena province, wetland ecosystems have been fragmented and degraded since the eighteenth century, when the land started to be reclaimed for agricultural purposes.

Birds are one of the main taxonomic groups associated to wetland ecosystems, since these systems represent one of the most important habitats for both migratory and non-migratory bird species (Kirby et al. 2008). Hence, they have been extensively used as an indicator taxon for biodiversity in wetlands (Amano et al. 2018). These systems provide essential wintering and breeding grounds for migratory species, and represent important stop-over areas during migration (Kirby et al. 2008, Bezzalla et al. 2019). Consequently, the relationship between wetlands and birds have sparked the interests in management, to preserve both local and regional biodiversity through conservation efforts (Bezzalla et al. 2019). The maintenance of healthy wetlands is considered essential to ensure the survival of waterbird populations and associated biodiversity. Most species, however, have been recorded to be declining since the 1980s (Kirby et al. 2008, BirdLife International 2021), mainly following habitat loss due to habitat fragmentation, which increases the area affected by anthropogenic stressors and decreases connectivity (Tozer et al. 2010).

Although avian species are well studied and some populations have recovered due to successful management actions (Amano et al. 2018, Massa & Borg 2019), the ongoing overall decline suggests that more efforts should go into habitat restoration and conservation. Avian population trends have extensively been used in conservation to identify environmental variables driving patterns associated with increasing and/or declining communities (Seoane & Carrascal 2008). Consequently, areas with high biodiversity levels and ecological importance were designated as protected areas, with the aims to promote the maintenance of ecologically important migration routes, re-establish lost populations, and the growth of existing ones (Kingsford et al. 2016). The main example in Europe is the creation of Natura 2000 network, which provides a legal framework for the protection of biodiversity in the EU, also by designing as Special Protection Areas (SPAs) the most important sites for birds' occurrence. To quantify the effectiveness of these areas and related management policies, long-term monitoring programs have been adopted globally (Schmeller et al. 2012, Reif 2013, Badia-Boher et al. 2019).

Following extensive habitat loss, artificial wetlands have been considered and established to compensate for the loss of natural habitats (Ma et al. 2004). The implications these artificial and natural habitats are having on avian populations, however, remain largely unknown at both local and regional scales. Natural wetlands seem to accommodate more diverse communities (Sebastián-González & Green 2016, Giosa et al. 2018), but there are species-specific differences in habitat selection that highlight the importance of artificial wetlands in sustaining different waterbird species (Bellio et al. 2009, Giosa et al. 2018). Although the complementarity of these systems has been pointed out (Kloskowski et al. 2009), conservation outcomes on waterbirds often seem to be highly dependent on the size, shape and distance to urban and/or other wetlands (Murray et al. 2013).

Quantitative assessments of local bird populations are lacking and/or often geographically biased towards few dominant countries (Dessborn et al. 2011). In birds, recent assessments on global conservation efforts revealed majority of studies being confined to North America or Western Europe, while conservation initiatives were present but poorly assessed elsewhere (Holm et al. 2011, Christie et al. 2021). Further biases are also on species selection in conservation assessments, with research efforts skewed towards certain species (Ducatez & Lefebvre 2014). For instance, the conservation of the common coot Fulica atra has been extensively studied due to their specific habitat requirements, while we lack knowledge on many Anatidae with similar narrow habitat preference (Holm et al. 2011).

Italy represents an important area for many migratory species, as stopover between their wintering and breeding grounds (Schmaltz et al. 2018, Giunchi et al. 2019). In the Modena (Italy) province alone, wetland ecosystems have been fragmented and degraded since the eighteenth century, when the land started to be reclaimed for agricultural purposes. Although water bodies are still present, farmlands currently occupy majority of the province (Cazzola 2013), with possible significant ecological implications on the local biodiversity. Within an area also known as Mirandola Plain, the development of artificial wetlands for conservation can sustain both resident and migratory populations. Therefore, to quantify both the presence and temporal trends of avian communities in the area is essential to contribute building a wider scenario on global biodiversity and conservation efforts.

Accordingly, by conducting systematic censuses in three adjacent artificial wetlands in the Modena province from 2005 to 2019, our main objectives were to i) assess temporal trends of guild abundance and biodiversity, ii) identify dominant species and quantify their population trends, iii) identify species of conservation concern and quantify their population trends. We finally discuss our findings, resulting from one of the longest time-series analyses on the avian biodiversity of Italian wetlands, in the light of the importance of the wetlands examined in conservation.

MATERIALS AND METHOS

Study area

We conducted bird censuses in the largest Italian plain, the Po Plain, within the Emilia-Romagna region. Specifically, the Mirandola Plains (Fig. 1) has been the main study site of an extensive research on avian brood parasitism (Campobello & Sealy 2009, 2010, 2011, 2020, Esposito et al. 2021). We surveyed bird communities present in three adjacent artificial wetlands:Valli di Fossa (VDF), Valli di Mirandola (VDM) and Valli Finalesi (VFI). The distance between the closest wetlands' sections is approximately 12.33 Km and 520.60 m between VDF – VDM and VDM – VFI, respectively, as quantified with ArcGIS PRO. The freshwater bodies were created as a result of measures adopted in the region during 1995-2004, aiming to restore habitats and protect local flora and fauna (Marchesi & Tinarelli 2007).

Wetlands in VDF were created from an exhausted clay pit, whose naturalization was completed in 2000. The area consists of several protected water bodies of a total of 30 ha, with water depth ranging from 2 to 4m. Contrastingly, VDM is composed of an intricate mosaic of wetlands and floated-meadows, which extends across hunting posts and a Special Protection Area (SPA, according to the European Union Directive on the Conservation of Wild Birds, 2009/147/EC) that includes 555 ha of protected land, coded as IT4040014. Finally, wetlands from VFI extend for about 327 ha and consist of aquaculture facilities, tailing ponds, and a sewage farm. Part of the area is included in the SPA coded as IT4040018 (Tinarelli 2005).

Sampling design

Bird communities were monitored monthly for nine non-consecutive years (2005, 2006, 2008-2011, 2017-2019) by volunteers based at the Modena Ornithological Station (hereafter, SOM). Volunteers at SOM conducted national bird censuses as appointed by ISPRA (National Institute for the Environmental Protection) in national and international projects (e.g., International Waterbird Census), which includes surveying every second decade of the month. While 71% of surveys occurred as per schedule, other had to be moved to the first or third decade of the month due to adverse weather conditions. Surveys were conducted following the list from Baccetti et al. (2002) for aquatic species with the addition of all diurnal raptor species (Accipitriformes and Falconiformes).We selected 42 equidistant census points, featured by a good visibility. We selected a different number of points per wetland, proportionally to the area covered; 7 points in VDF, 28 in VDM and 7 in VFI. Census points were reached by car or using walking paths, depending on

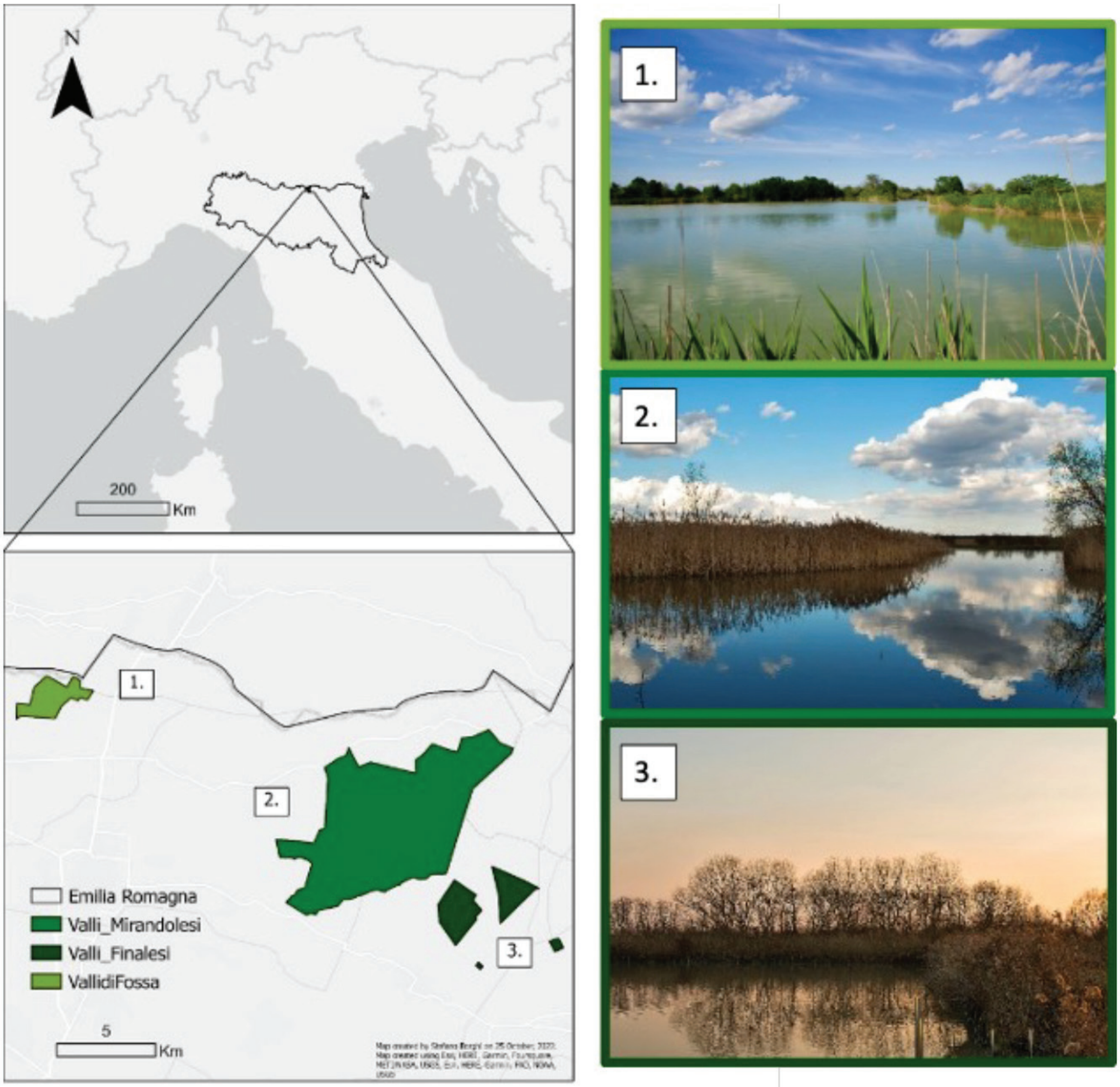

Figure 1. Distribution of the three artificial water bodies surveyed in this study in the Po Plain: (1) Valli di Fossa, (2) Valli Mirandolesi and (3) Valli Finalesi.

their accessibility. Four teams were appointed across wetlands during each census day: two in VDM and the remaining two between VDF and VFI. Each team consisted of at least two surveyors, one of which had to be ISPRA certified. During surveys, the teams spent a minimum of 10 minutes and no longer than 30 minutes per survey point, depending on the number of individuals counted. Double counts between neighbouring points were checked at the end of each census at the ornithological station. We classified the identified species as belonging to nine guilds: Ducks (Anatidae, subfamily Anatinae), Swans & Geese (Anatidae, subfamily Anserinae), Cormorants (Phalacrocoracidae), Shorebirds (Charadriiformes, family Laridae excluded), Gulls & Terns (Laridae), Raptors (Accipitriformes, Falconiformes and Strigiformes), Rails & Cranes (Gruiformes), Grebes & Divers (Podicipedidae and Gaviidae) and Large wading-birds

(Phoenicopteridae, Ciconiidae, Threskiornithidae and Ardeidae). The systematization of the registered taxa follows the IOC World Bird List (version 12.1).

Statistical analysis

To assess temporal trends of all avian guild abundance across the three macro areas, we quantified the relative indices by using the rtrim package (Bogaart et al. 2020; version 2.1.1) on R Studio (version 2022.02.3), which is a re-implementation of the software TRIM (Trends and Indices for Monitoring Data, Van Strien et al. 2004). All indices were calculated using the Linear (switching) trend model 2, which estimates population trends assuming a site-effect and a log-scale linear effect of time in case of missing counts (Pannekoek & Van Strien 2005). Although we acknowledge that survey detectability can be an issue and affect the results under the TRIM approach (Sanz-Pérez et al. 2020), we also consider the resulted trends informative and a solid baseline for future research.

Across all guilds, we considered species with a frequency $p_i > 0.05$ as dominant (Turcek 1956) and therefore we selected them for analysis. Species of conservation concern were instead selected by computing the index of Ornithological Value (IVO) using the formula proposed by Massa & Canale (2008) (Electronic Supplementary Materials, ESM, ESM 1) and built from Birdlife International (2021). We then quantified indices and trends of dominant species and species of greater conservation concern as per guilds, by using the re-implemented TRIM software in R Studio. Finally, guilds and species trends were classified using the six categories proposed by Klvanova et al. (2009) and still adopted in current investigations (Brlik et al. 2021), i.e., strong increase, moderate increase, stable, uncertain, moderate decline and strong decline.

Diversity indices

Guild trends were also investigated by computing the Shannon index (H') and Pielou species Evenness (J') (Pielou 1966), since the imputed guild indices obtained with TRIM do not take into account relative species abundances. Indexes were used to identify whether guild trends correspond to similar trends in biodiversity level. The Shannon index represents a commonly used approach to measure changes in species richness (Buckland et al. 2005). We could not quantify these indices to compare locations as few species were not represented every year or in some locations, making the Shannon index unreliable. We also could not quantify the diversity indices for the guilds of Cormorants, Swans & Geese and Grebes & Divers because of the low number of species within each guild.

RESULTS

A total of 543,441 individuals were counted across all guilds in 2005-2019. The highest species richness was recorded in 2008 (91 species across 9 guilds), while the lowest was recorded in 2005 and 2018 (83 species across the same guilds). Overall, no surveys were conducted in 2007 and 2012-2016, which severely impacted the robustness of the model. Species that never occurred during the 2005-2019 period were removed from the list, and populations' trends were analysed from the three wetlands combined, due to the limited spatial coverage. As the switching linear trend model virtually never fitted a log-linear distribution for both guilds and individual species analyses, we could not show p-values. This was likely caused by the many consecutive missing years from 2012 to 2016. Trim indexes, however, are still considered indicative of the local avian communities' temporal trends in the study area, while trend differences between habitats or functional groups could not be modelled (Williams & De la Fuente 2021).

Guild temporal trends

By looking at guild population size indices, a great variability in temporal trend was detected between guilds during 2005-2019 (Fig. 2; ESM 2). Four guilds resulted increasing, including large Wading birds (+9.82%), Cormorants (+10.66%), Swans & Geese (+16.14%) and Raptors (+18.45%), while Shorebirds (-3.20%) experienced a moderate temporal decline, and Gulls & Terns (+1.33%) appeared having stable populations over the study period. The analysis revealed uncertain trends for the remaining three guilds, including Rails & Cranes (2.77%), Grebes & Divers (-0.34%) and Ducks (+2.64%).

Species population trends

Five dominant species were identified from four different guilds in 2005-2019 (Fig. 3, ESM 3), including the Mallard (*Anas platyrhynchos*; Ducks, p_i = 0.31), the Eurasian Teal (*Anas crecca*; Ducks, p_i = 0.11), the Eurasian Coot (*Fulica atra*; Rails & Cranes, p_i = 0.06), the Northern Lapwing (*Vanellus vanellus*; Shorebirds, p_i = 0.13) and the Black-headed Gull (*Larus ridibundus*; Gulls & Terns, p_i =0.06). The analysis revealed majority of the dominant species investigated having stable populations, including the Mallard (-0.64%) and the Black-headed Gull (+0.12%). Contrastingly, moderate trends occurred in the Eurasian Teal (moderate increase; +2.97%) and the Northern Lapwing (moderate decline; -3.65%), while uncertain was the Eurasian Coot (-3.35%).

By looking at the highest IVO values, we identified seven species of conservation concern for analysis, including the Ferruginous Duck (*Aythya nyroca*; IVO = 2.10), the Red Kite (*Milvus milvus*;

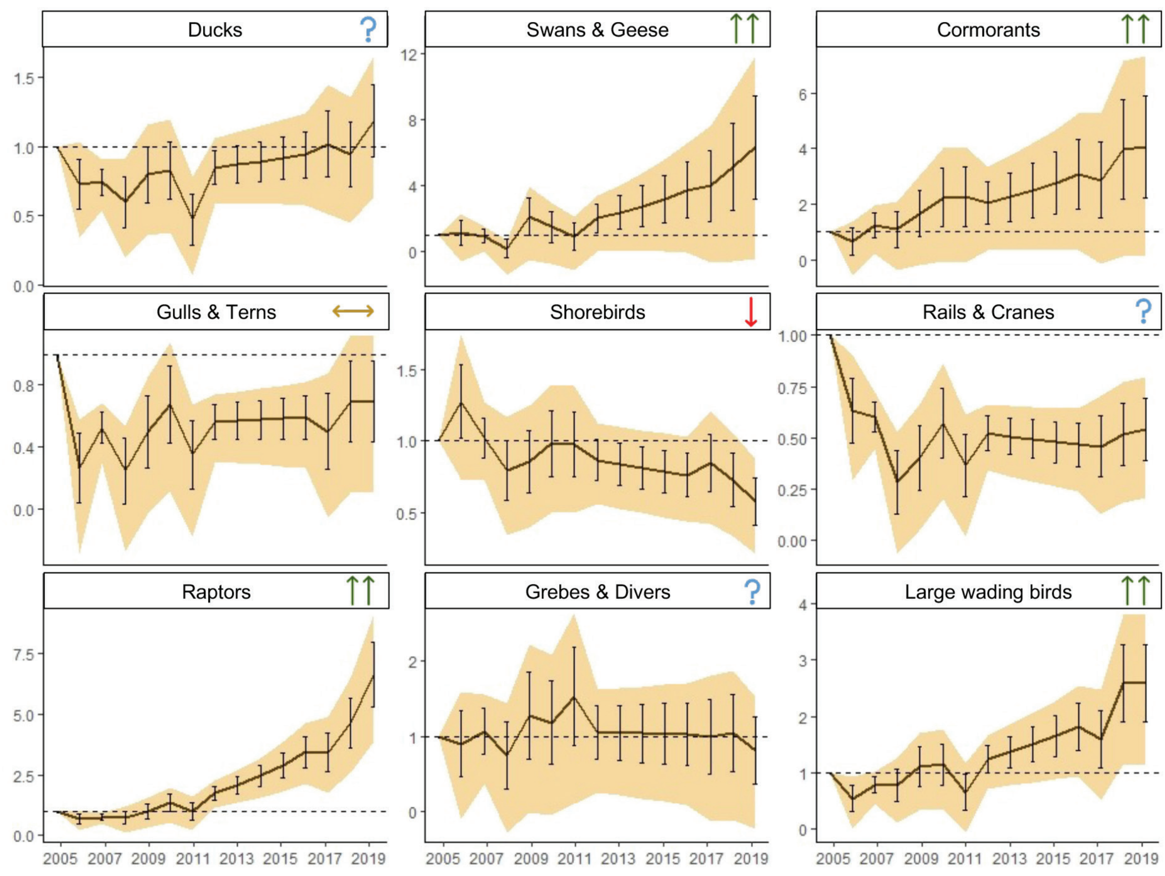

Figure 2. Imputed population size indexes (y axis) of avian guilds estimated using a Linear Trend Model in TRIM. Trends are shown with related SE (error bars) and confidence intervals (in yellow). Temporal changes are visualised starting from the reference recorded abundance in 2005 (imputed population size equal 1; dashed horizontal line). Trend classification is shown with green and red arrows for increasing and decreasing trends respectively (one for moderate and two for strong). Uncertain trends are shown with blue question marks, and stable trends have yellow arrows.

IVO = 2.20), the Hen Harrier (*Circus cyaneus*; IVO = 1.70), the Red-footed Falcon (*Falco vespertinus*; IVO = 2.20), the Ruff (*Calidris pugnax*; IVO = 1.85), the Great Snipe (*Gallinago media*; IVO = 2.10) and the Little Gull (*Hydrocoloeus minutus*; IVO = 1.70). Since some species occurred in low frequency over the study period, those species were excluded from analysis due to the low resolution of the trend indexes, including the Red Kite, the Great Snipe and the Little Gull. Within the remaining species (Fig. 3; ESM 3), the Hen Harrier (+13.40%) and the Red-Footed Falcon (+21.32%) temporally increased, while the Ruff moderately declined (-7.91%) and no clear trend was detected for the Ferruginous Duck (+6.30%).

Diversity indices

None of the guilds analysed maintained a constant number of species during the 2005-2019 period, making Shannon indices hard to compare (Tab. 1). The lowest species richness (S) was recorded for the Rails & Cranes (5 species in 2005, 2017, 2018 and 2019), while the highest was for the Shorebirds (27 species in 2006, 2008 and 2017). The highest Shannon index was recorded for the Raptors in 2010 (0.80), while the highest Evenness index was found in the same guild, but in 2008 (0.77). The lowest Shannon and Evenness indices were found for the Rails & Cranes in 2011 (0.12 and 0.16, respectively). Both indices shared a common trend in each guild during the 2005-2019 pe-

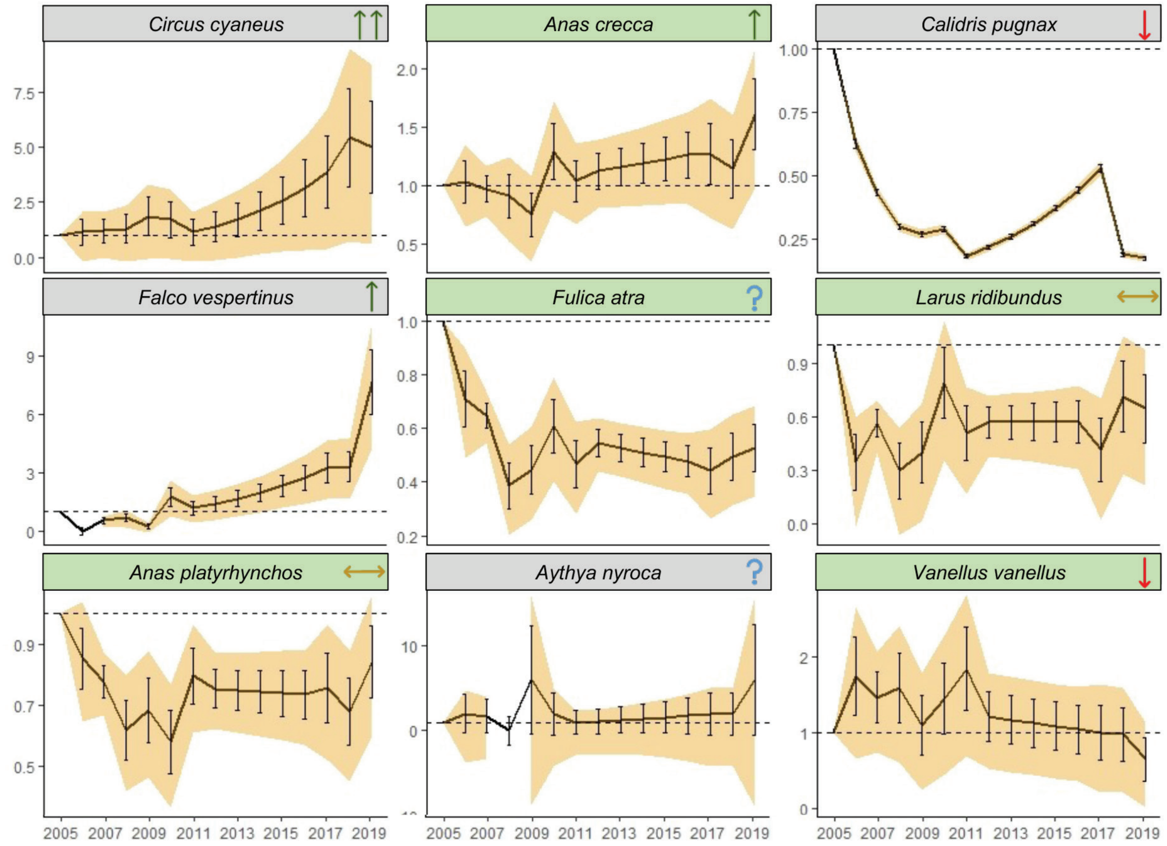

Figure 3. Imputed population size indexes (y axis) of dominant species and species of conservation interest estimated using a Linear Trend Model in TRIM. Trends are shown with related SE (error bars) and confidence intervals (in yellow). Temporal changes are visualised starting from the reference recorded abundance in 2005 (imputed population size equal 1; dashed horizontal line). Dominant species are shown in green, while species of conservation interest in grey. Trend classification is shown with green and red arrows for increasing and decreasing trends respectively (one for moderate and two for strong). Uncertain trends are shown with blue question marks, and stable trends have yellow arrows.

riod. They appeared to have negative temporal trends in most guilds, including Raptors, Large Wading birds and Gulls & Terns. Positive trends were revealed for the Ducks and Rails & Cranes, while no temporal trend was detected for the Shorebirds.

DISCUSSION

Overall, we found the artificial wetlands in Mirandola Plain to host a significant number of species. Indeed, the number of species recorded annually was either higher or in line with the species diversity reported from other natural and artificial wetlands around the globe, despite the small size of our study site (Murray et al. 2013, Sebastián-González & Green 2016). Such a high number of species supports previous investigations on this area (Giannella et al. 2021). Species diversity, as well as the positive temporal trends in most guilds, suggests that these wetlands may be successfully sustaining healthy and increasing avian populations. However, since no environmental variables were taken into account (e.g. Triolo et al. 2011), we can not speculate on the causes in temporal changes in abundance. Being some of the species migratory (Kirby et al. 2008), functional connectivity should be considered and ensured on regional scales, rather than locally, since quality and quantity or both artificial and natural water bodies in adjacent regions can impact the persistency of these species (Zamberletti et al. 2018). Nonetheless, successful local conservation initiatives can provide a framework on the right characteristics necessary for different species to persist and thrive, and therefore, to increase the effectiveness of artificial wetlands in conservation (Giosa et al. 2018).

The results here obtained for guilds need, however, to be interpreted with caution, since trends of guilds that include a high number of species may not be representative of temporal trends of individual species (Dinesen 1983). Quantifying individual species trends is essential to create a wider scenario on bird populations dynamics, but assessments of species population trends can be challenging. Trends are often influenced by contrasting responses to conservation actions, temperature fluctuations, or a multitude of other variables (Marchowski et al. 2018, Pavòn-Jordàn et al. 2020). Moreover, different species are unevenly represented in the literature. For instance, common species are usually less studied than vulnerable or threatened species whose conservation status is often prioritised (Inger et al. 2014). Nevetheless, declining populations in common species are likely to have deleterious ecological consequences, as the predominant abundance and ecology of common species define the entire ecosystem structure and functionality (Inger et al. 2014).

Contrastingly, if few species represent dominant communities within a guild, these species can significantly influence the trend of their respective guilds. For instance, the moderate decline in shorebirds can be primarily driven by the temporal decline in North-

Table 1. Guild species richness (S), Shannon diversity index (H’) and Evenness (J’) during the 2005-2019 period. All values are indicated as mean [± SE].

Guild	S	H’	J’
Ducks	12.55 [± 0.53]	0.35 [± 0.01]	0.32 [± 0.01]
Rails & Cranes	5.55 [± 0.17]	0.20 [± 0.01]	0.27 [± 0.02]
Shorebirds	24.44 [± 0.75]	0.69 [± 0.02]	0.50 [± 0.01]
Gulls & Terns	8.11 [± 0.61]	0.37 [± 0.03]	0.41 [± 0.03]
Large wading birds	13.33 [± 0.29]	0.72 [± 0.01]	0.64 [± 0.01]
Raptors	12.11 [± 0.65]	0.73 [± 0.01]	0.68 [± 0.02]

ern Lapwings*,* since other shorebirds reported from the study area were rather poorly represented compared to the Northern Lapwing. The moderate decline of the species can be driven by a variety of factors, such as possible thermal anomalies that impact and reduce localised water bodies (Pavòn-Jordàn et al. 2020), as well as human disturbance (Cherkaoui & Hanane 2011) and the presence of numerous ground predators in the area (Bellebaum & Bock 2009). The Northern Lapwing has been repeatedly reported having declining populations across its entire geographical range since 1980s (Henderson et al. 2002, MacDonald & Bolton 2008), with predation pressure and habitat degradation been pointed as some of the main threats (Charkaoui & Hanane 2011). Although the population present in the study site was categorised as dominant, it did not occur in the same abundance as in other regions, and therefore its trend is unlikely to drive fluctuations in the overall European population. The presence of ground predators, such as foxes, and the extensive agricultural fields and practices around the wetlands, have been linked to lower density for the species across its geographic range (Douglas et al. 2021). Previous studies for northern Italy, however, reported the species being abundant in farmlands outside the surveyed wetlands, suggesting the local population may be underestimated (Sorrenti & Musella 2003). Our knowledge on the vegetation and water bodies in study area, however, is lacking, and we encourage the inclusion of water quality assessments in future ecological works.

Similarly to what hypothesised for the Northern Lapwing, predation can represent a major threat to Coot populations, since the species tend to nest on the ground and close to urban settlement (Walesiak et al. 2019). Previous studies, however, resulted in contrasting outcomes. Some did not find either predation or proximity to urban areas negatively affecting the species abundance (Walesiak et al. 2019), contrarily to other investigations (Ręk 2009). Alternatively, fluctuations in local abundance were found to be associated with seasonal changes in water depth (Ayu et al. 2021). Although predation pressure may have impacted the local community, it is more likely that changes in water levels within the study area, with associated changes in macrophytes abundance (Perrow et al. 1997), may have obscured the overall population trend, resulting in uncertain outcomes. In our study sites, reduced water quality from pesticides from adjacent agricultural fields and hunting may have impacted the abundance of Coots (pers. obs).

Other common species within the study area did not reveal concerning trends, being either increasing or stable. Some of these species are widespread across the Italian peninsula, and are now dominant in both natural and urban systems, with no apparent major differences in their eco-ethological features (e.g., growth rates, movements or abundance), such as Mallards (Baratti et al. 2009). Other migratory ducks, such as the Eurasian Teal, are known to winter in Italy, with long stopover durations in multiple water bodies not far from their wintering grounds (Zenatello et al. 2014, Giunchi et al. 2019).

Similarly to most duck species, Black-headed Gulls are known to inhabit inland water bodies across Europe (Skórka et al. 2012), hence their stable presence in the study area was expected. There is, however, widespread concern over the recent geographic expansion in other gull species from coastal to inland habitats (Zielinska et al. 2007, Lenda et al. 2010, Skórka et al. 2012). Although the diversity in gulls remain relatively lower in the study area, surveys reported a significant population of Yellow-legged Gull (*Larus michahellis*). Assessing the impact of Yellow-legged Gulls on Black-headed Gulls was beyond the scope of this project. Our results showed common species not severely impacted by the presence of predator gulls. As common species do not decrease in abundance over time, this indicates our study area may not be vulnerable to invasion.

Vulnerable species have often been targeted in ecological studies and, therefore, have greater potential to drive conservation initiatives. In this study, majority of species of conservation concern analysed are raptors, including the Hen Harrier and the Red-footed Falcon, and were found increasing during the study period. Both species are more likely to be found in farmland and forest habitats (Purger 2008, Calabrese et al. 2020, Fernàndez-Bellon 2020) while use wetlands mainly as hunting grounds (Fernàndez-Bellon 2020, Berlusconi et al. 2022). Habitat fragmentation and unsustainable agricultural practices are two of the main factors claimed as causes of their past population declines, although conservation actions have succeeded in promoting local and regional abundance increases (Slobodnìk et al. 2017, Calabrese et al. 2020, Sheridan et al. 2020). For instance, artificial nest boxes were placed in the Parma province (close to Mirandola Plain) and at some sites in Hungary, areas with some of the most important European breeding populations of Red-footed Falcon. These initiatives have promoted local abundance increases and the recolonisation of adjacent areas, including the wetlands here discussed (pers. obs.).

The remaining two species of conservation concern analysed are waterfowls, including the Ruff and the Ferruginous Duck, a wading bird and duck respectively. Ruffs are known to occupy wetland and agricultural habitats (Schmaltz et al. 2018), although in this study it experienced a moderate temporal decline, suggesting local environmental conditions might not be optimal for its survival. However, the species is known to have two distinct macro wintering populations: a European and a sub-Saharan population, as the Italian peninsula has never been taken into account as a possible wintering ground (Schmaltz et al. 2018). The presence of the species within the study area suggests these wetlands can represent an important stopover during the migration of sub-Saharan populations, while the moderate decline recorded is more likely to be attributed to environmental conditions within wintering and breeding regions.

The Ferruginous Duck is a potentially 'near-threatened' waterfowl with two of the major breeding populations occupying wetlands in North Africa and eastern Europe (Cherkaoui et al. 2016). The species displayed an uncertain trend during the study period, uncertainty commonly reported in many ecological studies due to frequently observed shifts in breeding distribution following local water level fluctuations (Djelailia et al. 2017) and scattered data available on wintering populations (Djelailia et al. 2017, Ashoori 2018). In this study, the uncertain trend could be attributed to the missing data through the study period, as well as habitat conditions. For instance, some water bodies within the study area can experience water shortages occasionally (pers. obs.). Despite the ongoing assessments on local vegetation richness within the study area, these water bodies may be too small to maintain stable environmental conditions and breeding populations of Ferruginous Ducks. Moreover, the increasing trends of some raptors could discourage new breeding pairs to settle in the area (Cherkaoui et al. 2016), as well as hunting (pers.obs.). Been the species never observed frequently within the study area and listed as threatened globally (SPEC1; BirdLife International 2017), local data of the species abundance are essential to solve the global trend and support the current species status (Djelailia et al. 2017).

Our results further corroborate the importance of the wetlands analysed in conservation. Although it is limited in space, our investigation spanned over many years, an aspect long pointed as crucial to obtain valuable predictive information (Culina et al. 2021). The presence of healthy populations of common species can contribute to maintain functional ecosystems which, in turn, sustain diverse bird communities. Indeed, species diversity was high, with a peak of 91 species in 2008 in approximatively 912 ha in total, and negative trends were most likely driven by larger European population trends from both breeding and wintering grounds. Most importantly, the number of species reported remained almost unchanged during the study period, further suggesting the effectiveness of these artificial wetlands. Although no comparisons with semi-natural systems were made, the study shows the importance of artificial water bodies for bird communities. Quantitative assessments on guilds and species can then be used to create a wider scenario on bird population dynamic and to promote further conservation initiatives to increase local and regional functional habitat connectivity for both local and migratory species

Conflict of interest

The authors declare they have no conflicts of interest.

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