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Peri-urban wetlands as biodiversity hotspots: the approach study of the waterbird community seasonal variation of Arnovecchio oasis in Florence province (Tuscany)

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Abstract - The aim of this work was to monitor the waterbird community throughout the year in an anthropized peri-urban wetland of Florence province. The sampling was conducted from January 2018 to December 2020 throughout all seasons of the year by direct observations, using binoculars and acoustic surveys. To evaluate bird biodiversity, we calculated the relative frequency, abundance and species richness, the Shannon-Wiener Index and evenness. We monitored 19 species, among which six were dominant species: *Anas platyrhynchos*, *Larus michahellis*, *Fulica atra*, *Podiceps cristatus*, *Aythya ferina*, *Chroicocephalus ridibundus*. Abundance, species richness and Shannon-Wiener diversity were highest in winter, while evenness was highest in spring; a Principal Component Analysis confirmed that Arnovecchio is an important wetland both for breeding (*Podiceps cristatus*, *Tachybaptus ruficollis*, *Anas platyrhynchos*) and wintering species (*Aythya ferina*, *Chroicocephalus ridibundus*). Most of the species were identified in autumn and in winter when this area may represent for some birds a protected refuge during the hunting season. Among the most observed species, *Aythya ferina* and *Chroicocephalus ridibundus* were absent in spring but were more common in winter. Among the nesting species, the most common are *Podiceps cristatus* and *Tachybaptus ruficollis*. The results of this study suggest a constant presence of birds during the whole year in this peri-urban area, thereby highlighting its relevance for biodiversity as well as for providing the opportunity to human visitors to enjoy its natural values in all seasons.

Keywords: Peri-urban wetland, Principal Component Analysis, Seasonality, Waterbirds

INTRODUCTION

Peri-urban wetlands have a great ecological importance both for people and their activities and for the conservation of biological diversity. These areas ensure fresh water supply, flow control, ground water availability, and can mitigate against climatic change and pollution (Stefanakis 2019). These areas also have high environmental, educational and recreational interest. They contribute, mainly in the lowlands, to global conservation (Rudd et al. 2002) which, according to Sustainable Development Goals (SDG) 11- Sustainable Cities &. Community - Ramsar Convention on Wetlands, will ensure inclusive, safe, resilient and sustainable human settlements, buffering the effects of climate change (Seifollahi-Aghmiuni et al. 2019).

If compared to rural and remote wetlands, urban wetlands are characterized by flashier hydrology,

higher nutrient and sediment loads, higher temperatures, more physical disturbance, more invasive plant species and herbivorous animals, greater fragmentation, fewer forested buffers, and greater distances between wetlands (Baldwin 2011). Non-native invasive plants are often more abundant in urban wetlands than rural in or remote wetlands, and although they can contribute significantly to the diversity of the community, species richness may be locally reduced due to competitive exclusion (Baldwin 2011). Nonetheless, urban wetlands are often hotspots of biodiversity, especially of birds and fishes, and may support species that are rare, native, and common that are important for conservation (Alikhani et al. 2021, Chiari et al. 2010, Yam et al. 2015).

Bird diversity and abundance in urban ecosystems are usually altered when comparing with wildlands. While some species may increase in abundance due to high resource availability, local diversity generally tends to decline with increasing urbanization (Kondratyeva et al. 2020). However, most of the studies pointed out that urban wetlands can host more diverse bird communities compared to rural wetlands, and large urban wetlands can support higher densities of water birds than rural wetlands of the same size (Alikhani et al. 2021, Rawal et al. 2021). The species having conservation importance can be found not only in large urban green spaces but also within commercial, industrial, and residential districts (Rudd et al. 2002; Blair 2004; Acar et al. 2007). This in turn indicates there is potential to enhance biodiversity in all of the urban habitat types with strategic interventions (Li et al. 2019).

The aim of this work was to describe the ornithological community of a peri-urban wetland located in the province of Florence, by conducting standardised surveys at regular intervals throughout the year.

MATERIALS AND METHODS

Study area

The study area (Fig. 1) is Arnovecchio, an internal and small wetland of Tuscany (about 204 hectares) in Empoli, the province of Florence. This town is the leader of the economic industrial District “Circondario dell’empolese valdelsa”, specialized in the leather, textile, and clothing Industries. In the surrounding of this area (Empoli, Montelupo fiorentino and Limite Capraia) the human population is about 70.000 inhabitants. Arnovecchio area is located in a paleomeander of the Arno River, which was modified during the XVI century by Cosimo I de' Medici; since the 1960s and for the next 40 years this area was a gravel pit which led to the formation of an artificial lake (Scamporrino 2006).

Arnovecchio is a rural area comprised among the small town of Montelupo at the East and Empoli at the West; Arno River is in the north of Arnovecchio wetland, whereas the Florence-Pisa-Livorno Great Communication Road and the railway connecting Florence to Pisa are in the south of the wetland. Because of anthropogenic activities, this wetland and its natural values are considered as threatened (Scamporrino 2006).

Different environments of artificial origin characterize this area, and after the abandonment of some of the industrial production activities, this wetland is now in phase of spontaneous naturalization processes, highlighted by the presence of many species of flora and fauna (http://www.zoneumidetoscane.it/it/arnovecchio-area-naturale-protetta). The Arnovecchio territory was in the list of the Protected Natural Areas of the Local Interest in Tuscany (ANPIL) under the Regional Law 49/95 that considered the natural areas in highly anthropized zones needing conservation and reconstruction of the original environment characteristics. Their attribution to Park, Natural Reserve or Natura 2000 site is currently in progress (https://www.regione.toscana.it/-/aree-naturali-di-interesse-locale-anpil).

This wetland is open to public and managed by the Empoli Municipality through the “Padule di Fucecchio” Research, Documentation and Promotion (R.D.P.) Centre; this area hosts many aquatic and terrestrial bird species. In this study, the most representative aquatic species were monitored throughout the whole year in the period from 2018 to 2020.

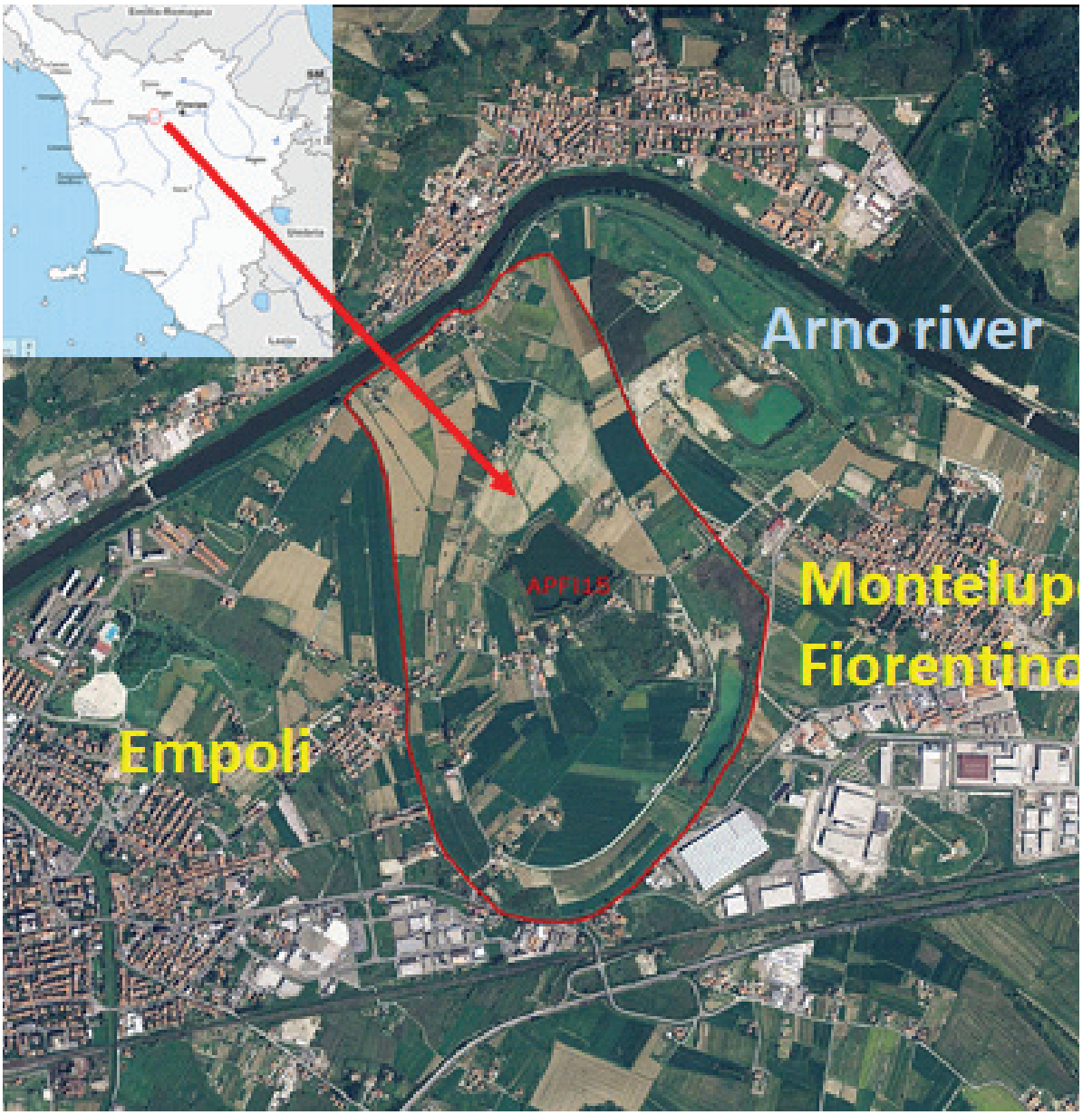

Figure 1. Map of the study site, the Arnovecchio oasis.

Survey Methodology

A triennial water bird survey from January 2018 to December 2020 was carried out in the Arnovecchio naturalistic oasis.

The survey was performed throughout all seasons of the year. Direct observations using binoculars "Nikon Aculon A211 8X42" and acoustic surveys through the identification of bird calls were carried out in this study. The monitoring seasonal sessions were 51 with intervals of about 20 days.

A trained observer carried out each survey. The duration of the survey was 3 hours and 45 minutes for every of the four observation points available to visitors. The observation points allow to the visitors

to see the same body of water from different angles. The observer recorded all birds that could be heard or seen.

Ecological Indices

To evaluate the biodiversity in this area, the following Ecological Indices were calculated:

- Relative frequency (pi): The ratio of the number of individuals of a particular species to the number of total individuals in the ornithological community. The equation for the relative frequency is pi = ni/N, where ni = number of individuals of the i^{th} species and N = ∑ ni. When pi is equal to or greater than 0.05, the species is considered dominant (Turček 1956, Oelke 1980, Fulco & Tellini Florenzo 2008, Angelici et al. 2012, Domokos & Domokos 2016); when pi is between 0.02 and 0.05, the species is subdominant. This index indicates the relative relevance of every species in a community.
- Abundance (N): The total number of individuals
- Species richness (S): The number of species. This index gives the population richness.
- Evenness (J'): The homogeneity of distribution of the different species abundances in a community. It depends only on the distribution of the abundances of individuals within the species (Lloyd & Ghelardi 1964, Pielou 1966).
- Shannon-Wiener Index: Shannon–Wiener Diversity index (H') (Wiener 1948, Shannon & Weaver 1949) is the most used index to assess species diversity (Hubalek 2000), and it depends on the number of species and their abundance.

Data Analysis

We calculated the above mentioned indexes averaging values of species abundance for each season (winter, spring, summer, autumn). We then analysed the variation in these indexes depending on the season, using the Kruskall-Wallis test. In tables were shown the values of χ 2 and P> χ 2: ***= P< 0.0001; **= P< 0.002; *= P<0.005. The season results were than compared with the Dunn's test: in tables the differences among seasons were shown (Tab. 2). All Indices were visualized on box plots (Fig. 2).

To determine the degree of similarity between season and bird populations, we conducted two principal component analyses (PCA) based on correlations. The first PCA was run on the ecological indices (N, S, H', J'), while the second was run the species for which we collected more than 80 observations (Gahbauer & Rashleigh 2021).

The Varimax rotation with Kaiser normalization was applied; the Varimax test rotates only the factors with eigenvalues-greater than-one (Sargentini et al. 2018). Varimax rotation (also called Kaiser-Varimax rotation) maximizes the sum of the variance of the squared loadings, where 'loadings' means correlations between variables and factors (Stephens 1996). Biplot graphics were created to visualise the distribution of the bird populations in different seasons. All the statistical analyses were performed using JMP® (2012)

RESULTS

Bird population description and Dominance in breeding and wintering seasons

In this study, 3510 individuals belonging to 19 species of aquatic birds were counted (Tab. 1). Mallard *Anas platyrhynchos*, Yellow-legged Gull *Larus michahellis*, Common Coot *Fulica atra*, Great Crested Grebe *Podiceps cristatus*, Common Pochard *Aythya ferina*, Black-headed Gull *Larus ridibundus*, with a relative frequency higher than 5%, are dominant species (Turček 1956); Little Grebe *Tachybaptus ruficollis* and Grey Heron *Ardea cinerea* are subdominant. In Tab. 1 the Dominance (Turček 1956) in breeding and wintering is shown. Mallard, Common Coot and Yellow-legged Gull were dominant as both breeding and wintering species; the Common Pochard was dominant as winter species, while the Great Crested Grebe was dominant in the breeding season; Grey Heron was subdominant in both phenological seasons, while the Little Grebe was subdominant in the breeding season only.

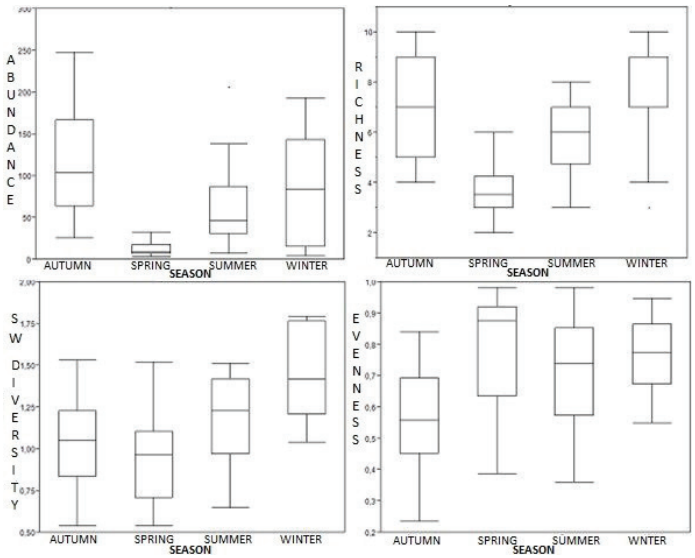

Figure 2. Box plots summarising variation in abundance, species richness, Shannon-Wiener diversity and evenness across the four seasons.

Table 1. Number of water birds recorded (n_i) during the whole year, and Relative frequency (pi) by Turcek (1956) in whole year, in the breeding season (March, April, May, June, July) and in the wintering season (October, November, December, January and February). In bold the dominant species: $p_i \geq 0.05$; in italic the subdominant species: $p_i \geq 0.02 < 0.05$.

	Species	Total number of waterbirds contacted (n_i), and Relative frequency (pi) during whole year		Relative frequency (p_i) for season	
		n_i	p_i	Breeding season	Wintering season
1	*Ardea alba*	3	0.0009	0	0.0012
2	*Anas crecca*	5	0.0140	0	0.0004
3	*Ardea cinerea*	129	*0.0368*	*0.02541*	*0.0451*
4	*Aythya ferina*	464	**0.1322**	*0.02541*	**0.1745**
5	*Aythya nyroca*	15	0.0043	0	0.0056
6	*Anas platyrhynchos*	783	**0.2231**	**0.2450**	**0.2288**
7	*Anas querquedula*	8	0.0023	0.0109	0
8	*Aythya ferina x Aythya nyroca*	3	0.0009	0	0.0012
9	*Chroicocephalus ridibundus*	436	**0.1242**	0.00363	**0.1729**
10	*Egretta garzetta*	6	0.0017	0.00907	0
11	*Fulica atra*	647	**0.1843**	**0.10526**	**0.1817**
12	*Gallinula chloropus*	3	0.0009	0	0.0012
13	*Larus michahellis*	794	**0.2262**	**0.45191**	**0.1470**
14	*Mareca strepera*	4	0.0011	0	0.0016
15	*Mareca penelope*	2	0.0006	0	0.0008
16	*Netta rufina*	2	0.0006	0.0018	0
17	*Phalacrocorax carbo*	25	0.0071	0	0.0080
18	*Podiceps cristatus*	100	*0.0285*	*0.0798*	0.0136
19	*Tachybaptus ruficollis*	81	*0.0231*	*0.0417*	0.0164

Ecological Indices

Abundance and species richness were highest in autumn and in winter and lowest in spring (Tab. 2). During autumn and winter, the most abundant species were: Mallard, Little Grebe, Great Crested Grebe, Common Coot, Yellow-legged Gull, Black-headed Gull, Common Pochard, and Great Cormorant *Phalacrocorax carbo*. In spring, the most abundant species were: Mallard, Black-headed Gull and Great Crested Grebe.

The Shannon-Wiener diversity (Tab. 2) was highest in winter and lowest in spring and autumn. A different trend was shown by the evenness Index, which was highest in spring and lowest in autumn (Tab. 3).

This trend was graphically confirmed by the box plots. The box plot of the abundance representation has shown the lowest values in spring (minimum 3 individuals), while the highest values were found in autumn (248 individuals) (Fig. 2). During the summer, there was an anomalous peak in July, when 206 individuals were monitored, but among these 165 were Yellow-legged Gull individuals. The median values were lowest in spring (9.5) and highest in autumn (104). The lowest richness values (2 species) were shown in spring, whereas the highest values were shown in autumn and in winter (10 species). The median values were lowest in spring (3.5) and highest in winter (7). The Shannon-Wiener diversity (Fig. 2) was lowest in autumn (0.54) and spring (0.53), while was highest in winter (1.79). The median values were lowest in spring (0.96) and highest in winter (1.42). The evenness (Fig. 2) was lowest in autumn (0.23) and highest in spring (0.98). The median values were lowest in autumn (0.55) and highest in spring (0.87).

Fig. 3 shows the results of the PCA for the ecological indices: evenness higher in spring, whereas richness and abundance were higher in winter and autumn.

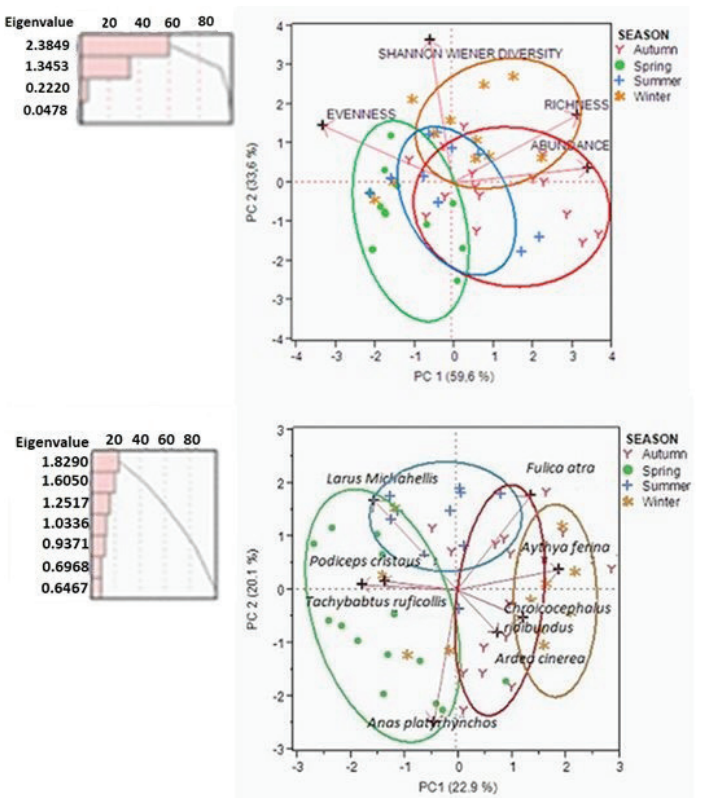

Figure 3. Principal component analysis for the ecological indices (top) and for the species (bottom) with more than 80 records per season.

Table 2. Variation in the four analysed ecological indices by season (mean ± standard deviation; χ^2 and P > χ^2 from Kruskal-Wallis test) using Dunn's multiple comparison test. Significant values: *** = P< 0.0001. N= Abundance, S= Richness, H'= Shannon-Wiener diversity, J'= Evenness

	Autumn	Spring	Summer	Winter	χ 2	P>χ 2	Dunn's test differences
N	115.33±64.49	13.21±8.91	66.20±61.35	84.81±69.52	23.44	***	Winter vs Spring; Spring vs Autumn
S	7.2±2.00	3.64±1.15	5.70±1.49	7.18±2.09	22.92	***	Winter vs Spring; Spring vs Autumn
H'	1.05±0.28	0.96±0.27	1.17±0.30	1.44±0.26	15.28	***	Winter vs Spring; Winter vs Autumn
J'	0.56±0.04	0.79±0.19	0.70±0.20	0.76±0.05	12.18	***	Spring vs Autumn

Table 3. Distribution of species with total number>80 by Season Dunn's Multiple Comparisons Procedure - Pairwise Comparisons significantly different. Significant values: ** = P< 0.01, * = P< 0.05.

Species	Autumn	Spring	Summer	Winter	χ^2	P> χ 2	Dunn's test differences
Anas platyrhynchos	40.36	6.54	11.2	9.00	14.92	**	Spring vs Autumn
Aythya ferina	26.93	0	3.0	13.0	3.25		n.s.
Chroicocephalus ridibundus	12.0		1.00	45.34	4.08		n.s.
Larus michahellis	23.77	3.57	37.10	6.00	13.50	**	Summer vs Spring; Spring vs Autumn
Ardea cinerea	3.82	2.75	1.00	8.11	8.50	*	Winter vs Summer
Podiceps cristatus	1.92	2.30	3.60	1.64	12.44	**	Winter vs Summer
Tachybabtus ruficollis	1.5	2.25	2.57	4.5	8.55	*	Winter vs Autumn
Fulica atra	22.71	1.67	15.0	19.33	8.12	*	Spring vs Autumn

Most representative species

The distribution along the four seasons of the species recorded more than 80 times is shown in Tab. 3. Among the Anatidae, the Mallard was recorded mainly in autumn. The Common Pochard was recorded mainly in autumn and winter, and was absent in summer. Among the Larids, the Black-headed Gull, was mainly found in winter and autumn, but was less abundant in summer and spring. The Yellow-legged Gull was found in all seasons and showed the highest number of records in summer and autumn, while in spring and winter its presence was low. The Grey Heron, belonging to the Ardeidae family, was found in all seasons with a very high number of records in winter. The Great Crested Grebe, belonging to the Podicipedidae family, was found in all seasons, with the greatest number of records in summer. The Common Coot, belonging to the Rallidae family, has been reported throughout the year. The greatest number of records was found in autumn and winter. The Common Coot showed a medium-low number of records in the spring-summer period. The Little Grebe was mainly seen in winter.

Fig. 3 shows the results of the PCA ran on the most represented species: spring was highly loaded with the nesting species Great Crested Grebe and Little Grebe, while autumn and winter were loaded with records from the Common Pochard, the Common Coot and the Black-headed Gull.

DISCUSSION

The number of monitored species in this research met the results of Panuccio et al. (2017) in Tor di Valle Tiber River and in Vallerano flooded quarry and of

Malavasi et al. (2009) in Torre Flavia area, Rome. These results did not meet the results of Angelici & Brunelli (2019) in the Regional nature Reserve of Nazzano, Tevere-Farfa (Latium, central Italy) and Bartolini (2007) in Fucecchio Marsh; the lower number of monitored species found in this study may be due to the characteristics of the Arnovecchio area, small and restricted. The Grey Heron and the Little Grebe have also been monitored by Angelici et al. (2012) in the Nazzano-Tever-Farfa Reserve. Furthermore, both in Arnovecchio and in Nazzano-Tever-Farfa Reserve (Angelici & Brunelli 2019) the Common Coot is a dominant species in all seasons, whereas the Great Crested Grebe was a dominant species in spring and summer. During the summer in Arnovecchio visitors can see the adults of Great Crested Grebe carrying their chicks on their back.

The dominant species found in this study are typical of internal wetlands of central Italy; in addition to these, there were the gulls that follow rivers and other source of water (ecological corridors) (Maciusik et al. 2010). Among the monitored species, the Ferruginous Duck is an endangered species in slow increase in Italy (http://www.iucn.it/scheda.php?id=-128929044).

The richness value agrees with the same ecological index found by Panuccio et al. (2017) and Malavasi et al. (2009) in two different wetlands of Latium.

The wetlands are very important for the wintering species (Lewis et al. 2019, Clipp et al. 2017 Malavasi et al. 2009, Hall 1997, Farina 1987, Fedrigo et al. 1989). Birds find in these areas a lot of food and protection against winter cold. Furthermore, Arnovecchio area represents a safe place (National Law 157/92) for many game birds during the hunting season; in fact, this area is in the list of the protected natural areas of local interest in Tuscany under the Regional Law 30/2015 “Conservation and valorisation rules for the regional naturalistic-environmental heritage”.

The low evenness values found in this research in autumn may be due to high presence of few species (Mallard, Yellow-legged Gull and Common Coot), while the high values found in spring may be due to the large amount of food and the lower competition among species and individuals. The results of the evenness met those found by Causarano et al. (2009) in the “Palude di Torre Flavia”. If compared with Elafri et al. (2016), in a study conducted in a natural National Park of north-eastern Algeria, the evenness index was lower, whereas the richness values were very high in the Algerian research and the Shannon Wiener diversity in winter was similar.

The PCA results confirmed that the richness and the abundance were identified in winter and in autumn, because the high number of species in this period. The evenness was identified in spring, because the lower and evenly distributed number of species; most of monitored birds in this period belonged to nesting species. The latest Ecological Index may be influenced by the nesting species, mainly the Great Crested Grebe and the Little Grebe that found favourable environmental conditions.

Among the most representative species, the Mallard is a game species in Italy. The Mallard seeks protection in the interior and protected areas of Tuscany, especially during the autumn. This species is susceptible to the anthropic disturbance (Pease et al. 2005) and its presence may be conditioned by the human activities, lesser during the autumn because the bad weather.

The Common Pochard is a game species (National law 157/92), founding in Arnovecchio a protected area in autumn and winter.

Malavasi et al. (2009) found the Common Pochard both as wintering species during the cold season and as breeding species in Spring. Angelici & Brunelli (2012) found in Regional Reserve Nazzano, Tevere-Farfa, Mallard individuals mostly in winter, while the Common Pochard was monitored both in winter and in spring. Lee & Kang (2019) found the Mallard, in a temperate zone of South Korea, mostly in Autumn-Winter and the Common Pochard only in winter. Causarano et al. (2009) found the Mallard as dominant species during the spring. This species was found mostly in Tor di Valle area and showed scarce presence in Vallerano flooded quarry (Panuccio et al.

2017), while the Common Pochard was monitored only one time in Tor di Valle, while has shown high presence in Vallerano during the Winter; Vallerano area meet the characteristics of Arnovecchio area, because both flooded quarries in the past.

The high presence of the Black-headed Gull in Arnovecchio during the Winter may be due to the presence of ecological corridors (Maciusik et al. 2010) represented by interior wetlands and the Arno River. Even the Yellow-legged Gull, mostly monitored in Summer and Autumn, exploited the ecological corridors of the interior Tuscany. The presence of these species in different seasons of the year may be due to different ecological and feeding behaviour, that allow avoid an overlap of both species in a confined and small area.

In a study in an inland urban area near Vistola river the Black-headed Gull was monitored in Winter, because rivers and wetland represent ecological corridors; the presence of the Black-headed Gull is strongly associated with river valleys, rivers, and lakes (Maciusik et al. 2010). Both gulls were surveyed in high number in Tor di Valle; in Vallerano only the Yellow-legged Gull was monitored in few cases (Panuccio et al. 2017). The results found in this study for the Yellow-legged Gull didn't agree with Malavasi et al. (2009) that found this species only in Winter.

The large number of Grey Heron individuals in Arnovecchio during the winter may be due to the lesser human presence during this period. Malavasi et al. (2009) in Torre Flavia wetland found the Grey Heron only in winter. Panuccio et al. (2017) found the Grey Heron in winter along the Tor di Valle Tiber river and in Vallerano flooded quarry.

The Great Crested Grebe, monitored in Arnovecchio area mostly in spring and in summer, prefer as nesting places the internal wetlands (Bartolini 2007).

The higher presence of Little Grebe in winter in Arnovecchio may be due to the ecological behaviour of the species, shy and susceptible to the human presence. These results met Ceccobelli & Battisti (2010) that found this species from October to June in Torre Flavia. Even Panuccio et al. (2017) monitored the Little Grebe in Vallerano area during the winter. On the contrary, Causarano et al. (2009) found in some cases the Little Grebe dominant in spring in Torre Flavia area.

The Eurasian Coot, most monitored in Arnovecchio in autumn and winter, prefers open environments as wintering places, as lakes, sheltered bays, lagoons etc. Malavasi et al. (2009) didn't find significant differences between winter and spring for the Common Coot. Angelici & Brunelli (2012) found this species during the winter, while Battisti et al. (2020) found the Common Coot in Torre Flavia area during the spring. Lee & Kang (2019) monitored this species only in autumn-winter. The Common Coot was sporadically present in Tor di Valle and it was more present in Vallerano area (Panuccio et al. 2017). Causarano et al. (2009) found the Common Coot as dominant species during the spring.

In conclusion, the results of this study confirmed how Arnovecchio is an important peri-urban wetland area, rich in bird biodiversity and abundance of both breeding and wintering species. The most representative species are the wintering species that found in this area shelter and food during the hunting season. These results agree with Elafri et al. (2016) in a Natural national park of North-western Algeria. Conversely, the evenness was highest in spring, where most of monitored birds in this period belonged to nesting species, evenly distributed. Important nesting species are the Little Grebe and the Great Crested Grebe. The constant presence of birds throughout the year in Arnovecchio oasis allows the visitors to enjoy its natural values in all seasons.

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