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Comparative study of the avifauna of three Mediterranean wetlands: Two urban wetlands (Oued Martil and Oued El Maleh, Tangier-Tetouan, northern Morocco) and Merja Zerga (ramsar site) and the impact of urbanization on these ecological niches

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Abstract The Mediterranean basin is a global hotspot for biodiversity, and wetlands are particularly recognized for their role in this hotspot. Moroccan wetlands, which are part of the broader Mediterranean system, provide habitats for endemic, threatened, and migratory species. Despite their recognized importance and the protection of several Moroccan wetlands, natural wetlands continue to be converted into agricultural lands and urban areas.They are facing anthropogenic pressures and losses in area and quality. Although these transformations have occurred, wetlands located in or near urban areas still harbor remarkable avian biodiversity. In this study, we compared the ornithological composition of urban Mediterranean wetlands, Oued Martil and Oued El Maleh (Tetouan, Northern Morocco), with the Ramsar site Merja Zerga, a classified and a protected wetland. The results show that the urban wetlands and the Ramsar site have in common 66% of families and 43% of species, including several species with significant conservation statuses. In the same way, waterbird species richness was comparable across unprotected and protected coastal wetlands. Likewise, urban wetlands of Oued Martil and Oued El Maleh, as well as the Ramsar site, support the same remarkable, heritage and IUCN- listed species. On the other hand, avian species richness was lower in urban wetlands of the Oued Martil and Oued El Maleh compared to the Ramsar site. In particular, fewer passerine were recorded, and the number of wader species was approximately two times lower in urban wetlands. These results suggest that urban wetlands can support rich and diverse bird populations and need to be protected and integrated into conservation efforts. However, they may also reflect signs of habitat degradation or reduced availability of key resources for bird species. More studies on phenology and long-term monitoring are essential to better understand the ecological significance of urban wetlands in Morocco and across the Mediterranean region.

Keywords: birds, wetland, biodiversity, ecology, urbanization, conservation

1. Introduction

Mediterranean wetlands are subject to natural and anthropogenic pressures, and have undergone a general metamorphosis. They are losing surface area and ecological and biological quality (Alikhani et al., 2021; Chedad et al., 2020; Green et al., 2002; Datri et al., 2024; Day et al., 2021; Ennabili et al., 2021; Lees et al., 2022;Perennou et al., 2020; Taylor et al., 2021). In Morocco, coastal wetlands are important for local, Mediterranean and global biodiversity (Ennabili et al., 2021; Green et al., 2002; Mars et al., 2023a). Firstly, their diversity is linked to climatic variants (humid, subhumid, semi-arid or arid climate), their location (Mediterranean or Atlantic) and their hydrological regime (wadi, lake, lagoon, and estuary). As a result, they perform a variety of ecological functions and ecosystem services (Green et al., 2002; Point, 2010). As part of the Mediterranean biodiversity hotspot, they are home to a high rate of endemism, vulnerable species and others threatened with extinction (Balletto et al., 2010; Perennou et al., 2020; Regos et al., 2015; Sahbani et al., 2022). However, they are highly coveted, given the high rate of urbanization along the coast. Economic development, population growth and climate change

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(Day et al., 2021; Liu et al., 2021; Regos et al., 2015) are further challenges. What's more, the precise data available on their surface loss is insufficient (Balletto et al., 2010; Taylor et al., 2021; Alikhani et al., 2021; Perennou et al., 2020). For example, urban, peri-urban, small-scale and incidental wetlands are little studied or valued for their quality and roles, despite their importance (Green et al., 2002; Datri et al., 2024), and they can be home to remarkable resident, migratory and breeding avifauna (Datri et al., 2024; Alikhani et al., 2021; Ghosh & Pal, 2023; Livingston et al., 2020), providing information on their ecological and biological importance (Green & Elmberg, 2014).

The wetlands of the Tangier-Tetouan sub-region (Northern Morocco) are located on the major East-Atlantic flyway that is important for bird migration. They are the first environments used after crossing the Mediterranean, and the first choice of breeding and migratory species, given their quality and the availability of resources (Cherkaoui et al., 2007; Cherkaoui et al., 2016; Mars et al., 2023a). In addition, Mediterranean wetlands located on the East-Atlantic flyway are wintering, passage, stopover, resting, feeding and breeding sites for several species, many of which are heritage, threatened, rare, endemic and protected (Day et al., 2021; Green & Elmberg, 2014).

The Oued El Maleh and Oued Martil wetlands (Town of Martil, Tangier-Tetouan Region, Morocco) are highly urbanized and have been the subject of several studies. These include geological (El Hilali et al., 2023) and biological investigations to assess the degree of pollution (Belhaj & Kettani, 2013; Benajiba et al., 2013; Mghili et al., 2024), their vulnerability to climate change (Regos et al., 2015; Sahbani et al., 2022), their importance for flora (Ennabili et al., 2021; Hammada, 2007) and their ornithological value (Amezian et al., 2012; Mars et al., 2023a; Mars et al., 2023b).

In our research work, we have previously noted the ornithological and heritage importance of the Oued El Maleh and Oued Martil urban wetlands. These ecosystems are home to several remarkable, heritage, threatened, endangered, declining and endemic species, as well as actual and potential nesters in Morocco (Mars et al., 2023a; Mars et al., 2023b).

Merja Zerga is Morocco's largest and most extensively studied protected wetland. It has been classified as a biological reserve, a site of biological and ecological importance (SIBE) since 1980 and a Ramsar site of international importance for biodiversity since 2005 (Ramsar Site N°206-2005).

With the aim of assessing the impact of urbanization on the diversity and stability of avifauna, we compared the urban and peri-urban wetlands of Oued Martil and Oued El Maleh (southern Mediterranean coast) with a protected rural wetland, Merja Zerga, located on the Atlantic coast (Ramsar site)

This comparison is driven by the following hypotheses:

- Urbanization leads to a reduction in species diversity and a decline in the number of remarkable, endemic, rare, vulnerable and endangered species.
- Conservation status (Sibe, Ramsar) is a factor in the enrichment of remarkable and heritage species.
- Hydric, geological and floristic characteristics have an effect on avifauna biodiversity and heritage value.

2. Materials and Methods

2.1. Study areas

This study was carried out in three Mediterranean wetlands in Northern Morocco: two urban wetlands, Oued Martil and Oued El Maleh, and the Merja Zerga Ramsar site (Figure 1).

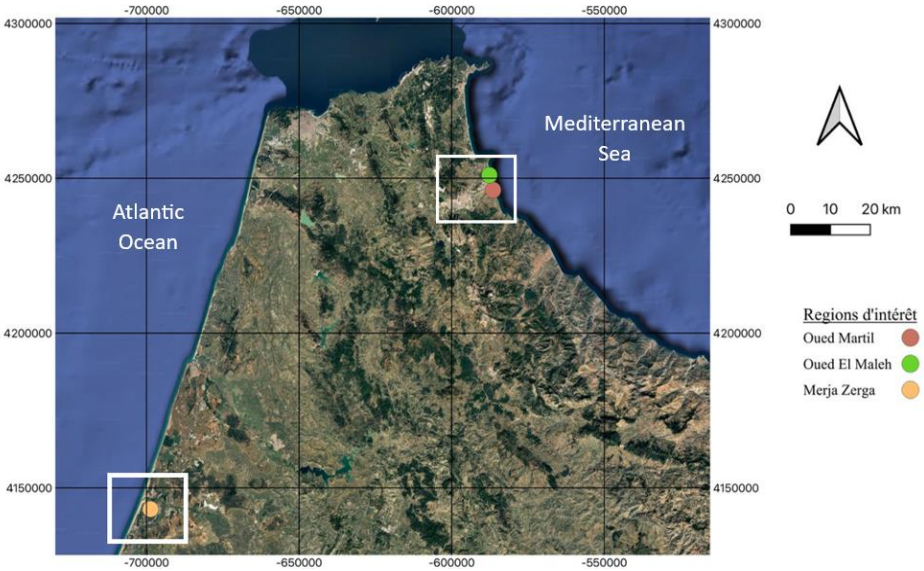

Figure 1 Location of the studied wetlands in Morocco: the urban wetlands of Oued Martil and Oued El Maleh on the Mediterranean coast (Northern Morocco); the Merja Zerga Ramsar site on the Atlantic coast (North-Western Morocco) (Google Maps November 30, 2024).

2.2. Oued Martil and Oued El Maleh urban wetlands

The Oued Martil and Oued El Maleh wetlands belong to the provinces of Tetouan and M'Diq-Fnideq (Northern Morocco), which boast an interesting hydraulic potential with an average rainfall of 700 mm/year and several water sources (Oued Martil, Oued El Maleh and Oued Amssa). These wetlands are located in the Martil watershed on the Mediterranean coast, in the urban areas of the cities of Tetouan and Martil (Figures 2 and 3).

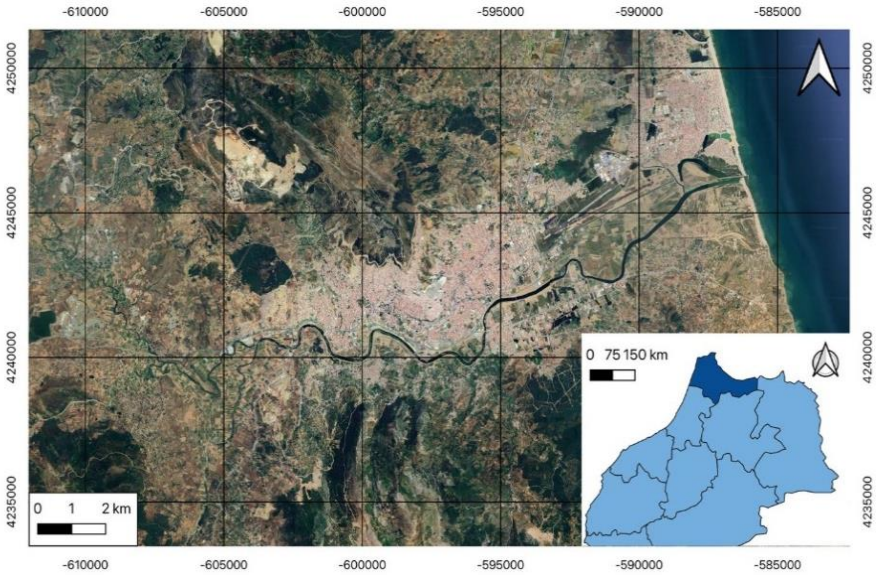

Figure 2 The urbanized wetland of Oued Martil, watercourse and estuary (Mediterranean coast) (Google Maps November 30, 2024): urban wetland of Oued Martil is located in the urban area of the cities of Martil and Tetouan, is close to several districts and human settlements. Urban development of the Martil plain and the cities of Martil and Tetouan, has resulted in the urbanization of the Oued Martil major bed and the reduction of the riparian zone.

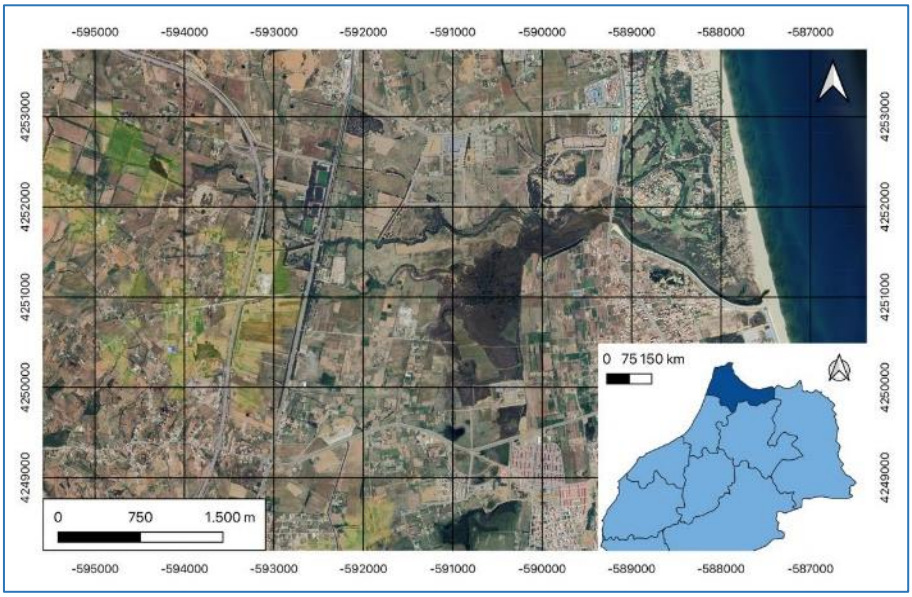

Figure 3 The urbanized wetland of Oued El Maleh, watercourse and estuary (Mediterranean coast) (Google Maps, November 30, 2024). The wetland of Oued El Maleh is located within the urban area of the city of Martil. The urbanization of the main riverbed and the estuary of Oued El Maleh have shaped the current state of this wetland ecosystem and has reduced the water surface, the beach, and the sand dunes.

The urban perimeter of the province of Tetouan is occupied by 1123 ha of forest, 133 ha of marshland, 4651.35 ha of agricultural land and 3075 ha of urbanized areas (Karrouchi et al., 2016). Several infrastructures have been developed close to or on the major bed of Oued Martil, Oued Samsa and Oued Chajra. Oued El Maleh and Oued Martil flow through the two cities of Tetouan and Martil and into the Mediterranean. The hydraulic regime is torrential in a Mediterranean climate, with an average annual temperature of 16°C and 700 mm of precipitation. The floodplain of the Oued Martil is the subject of several development projects (Basquin et al., 2022).

The climate is Mediterranean, with two distinct seasons: a cool, wet season from October to April, and a warm, sub-humid season from May to September. The Oued El Maleh has an intermittent flow and reaches the coast via an estuary, while the Oued Martil has several tributaries and sufficient flow to cross the coastal barrier via an estuary.

2.3. Merja Zerga wetland (Figures 1 and 4)

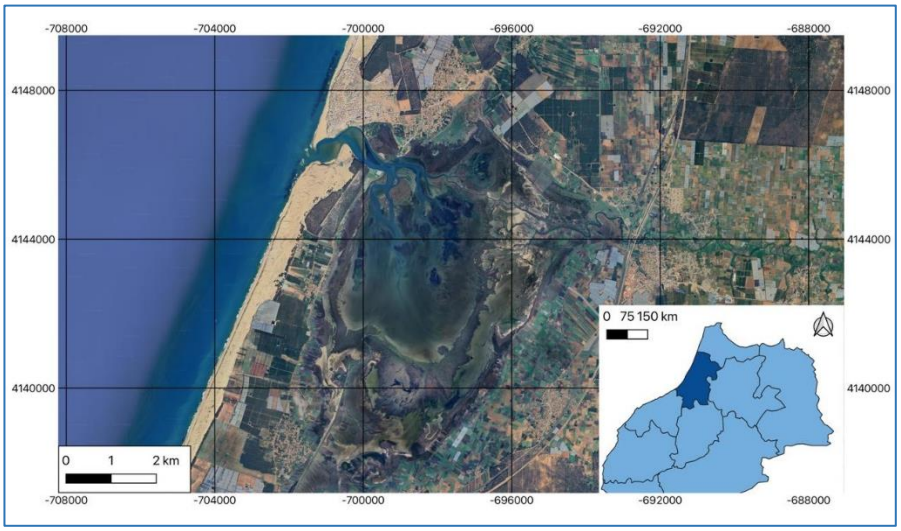

Figure 4 The Ramsar site Merja Zerga is a coastal Atlantic lagoon (Google Maps, November 30, 2024). Merja Zerga is the largest lagoon in Morocco. It is not as urbanized compared to the two wetlands of Oued Martil and Oued El Maleh.

Merja Zerga is located on the Northern Atlantic coast at the northwestern edge of the Gharb plain, south of the seaside village of Moulay Bousselham, 70 km north of the city of Kenitra and 35 km south of Larache (Morocco). It consists of a lagoon (Moulay Bousselham), beaches and sand dunes, marshes, and cultivated lands. Merja Zerga is a lagoon system fed with freshwater by two permanent watercourses, the Nador Canal and the Drader River.

The water regime is subject to tidal fluctuations and connects to the ocean through a narrow channel kept open by fishermen. The water depth depends on tidal influences and the amount of rainfall.

Merja Zerga lagoon belongs to thermo-Mediterranean subhumid bioclimatic zone, characterized by mild winters. The climate is characterized by irregular rainfall and the alternation of a dry season (from May to September) and a wet and cold season (from October to April) (Benmokhtar, 2023).

The collection of ornithological data in the two urban wetland areas, Oued Martil and Oued El Maleh, was carried out through bird monitoring. This monitoring was conducted from January 2021 to January 2023 through weekly field visits. The monitoring methodology consisted of point counts at fixed sites. The duration of each observation ranged from 30 to 60 minutes, depending on the number of birds and the season. All observations were made during daylight hours, from 6:00 AM to 6:00 PM, depending on weather conditions, accessibility, and light availability. The equipment used included binoculars for field observations and a camera to document the species. Species identification was carried out using the Delachaux and Nestlé bird guide (2021) and the Book of Birds of Morocco (Bergier et al. 2022). We recorder all reproductive indicators to evaluate species with breeding potential in the habitats in urban wetlands. All reproductive indicators were recorded, such as the presence of chicks, nests, courtship displays, territorial defense, and breeding plumage. Data collection on the birdlife of Merja Zerga was based on indirect sources from the available literature. Several avian scientific names were revised in accordance with recent taxonomic references.

2.4. Comparison

This study compared species, family, and functional group richness to evaluate the taxonomic and ecological composition of the bird assemblages. It also compared conservation and phenological statuses.

3. Results and discussion

3.1. Species Diversity in Terms of Number of Species and Families

Urban wetlands Oued Martil and Oued El Maleh, hosted 85 and 89 species, belonging to 43 families. In contrast, 180 species related to 56 families have been identified in the Ramsar site Merja Zerga (Cherkaoui & Alaoui, 2007). This study showed that 37 families (66%) are common to all three sites, mostly aquatic birds and passerines. Furthermore, about half of the recorded species are common to the three wetland areas. Regarding avian species richness, 78 species were found in both Merja Zerga and Oued Martil, and 79 species were recorded in both Merja Zerga and Oued El Maleh.

Several heritage and remarkable species are common to urban wetlands and protected wetland. Among these common species, the following can be highlighted: *Himantopus himantopus* (Recurvirostridae); *Phalacrocorax carbo* (Phalacrocoracidae); *Chroicocephalus ridibundus* (Laridae); *Anas platyrhynchos* (Anatidae); *Egretta garzetta* (Ardeidae); *Thalasseus sandvicensis* (Laridae); *Phoenicopterus* roseus (Phoenicopteridae); *Plegadis falcinellus* (Threskiornithidae); Ichthyaetus audouinii (Laridae); *Ciconia ciconia* (Ciconiidae); *Fulica cristata* (Rallidae) and *Fulica atra* (Rallidae) (Figure 5a, Figure 5b, Figure 5c) (Mars et al., 2023a; Mars et al., 2023b, Cherkaoui et al., 2007).

Figure 5a The urban wetlands of Oued Martil and Oued El Maleh provide habitats for several species during their migratory stopovers. These species use the urban wetlands for resting and feeding. Many species are common to the urban wetlands of Oued Martil and Oued El Maleh, and the Ramsar site Merja Zerga. A: Himantopus himantopus (Recurvirostridae) (Oued El Maleh); B: Phalacrocorax carbo (Phalacrocoracidae), Chroicocephalus ridibundus (Laridae), Anas platyrhynchos (Anatidae); C: Egretta garzetta (Ardeidae) (Oued El Maleh); D: Thalasseus sandvicensis (Oued El Maleh).

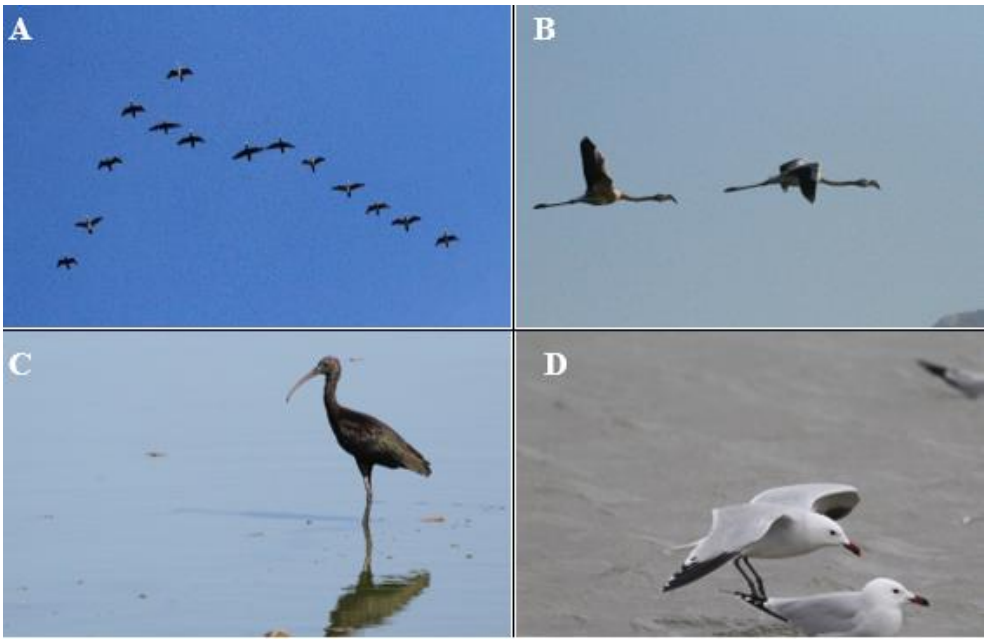

Figure 5b Several bird species depend on and use urban wetlands of Oued Martil and Oued El Maleh during their migratory journeys or wintering periods. Numerous heritage species are present in these wetland environments A: Phalacrocorax carbo (Phalacrocoracidae) (Oued Martil); B: Phoenicopterus roseus (Phoenicopteridae) is a former breeder in Morocoo(Oued Martil); C: Plegadis falcinellus (Threskiornithidae) is endangered in Morocco (Oued Martil); D: Ichthyaetus audouinii (Laridae), is vulnerable according to IUCN criteria (Oued El Maleh).

Figure 5c Some heritage waterbird species in urban wetlands of Oued Martil. A: Phoenicopterus roseus (Phoenicopteridae); B: Ciconia ciconia (Ciconiidae); C: Anas platyrhynchos (Anatidae); D: A vulnerable species (IUCN) and endangered in Morocco: Fulica cristata (Rallidae) and Fulica atra (Rallidae).

These results are unprecedented, given the high urbanization of the Oued Martil and Oued El Maleh wetlands, compared to the protected wetland Merja Zerga (Table 1). These results align with the conclusions of earlier studies. McKinney et al. (2011) found that urban wetlands can provide habitats for avian species in urban landscapes, support bird communities, including species not typically associated with wetland environments.

Table 1 Bird Families and Species Common to Three Mediterranean Wetland Areas: the Urban Wetlands of Oued Martil and Oued El Maleh, and the Ramsar Site Merja Zerga.

Common to the three wetland areas: Oued Martil, Oued El Maleh, and Merja Zerga	Common to the three wetland areas: Oued Martil, Oued El Maleh, and Merja Zerga	Common to the Oued Martil and Merja Zerga wetlands	Common to the Oued El Maleh and Merja Zerga wetlands
37 Families	83 species	78 species	79 species
66.07%	54.60%	43.33%	43.88%

Most of the avian families and species recorded in studied wetlands are associated with wetland habitats (Figure 6a, Figure 6b, Figure 6c) where they find resting and feeding habitats. Urban wetlands recorded less Scolopacidae (14 and 10 species), Anatidae (7 and 6 species), and Charadriidae (3 species) than Ramsar site (21; 14 and 6) . It may linked to the fact that most species in these families are specific and need a dense riparian vegetation cover. High urbnization has destroyed the vegetation cover in urban wetlands while the vegetation cover is dense in Merja Zerga. Anatidae heavily rely on wetlands and water bodies. Scolopacidae and Charadriidae frequent coastal and inland wetlands. Most are found in open environments (Tzortzakaki et al., 2018), and some prefer sheltered areas with vegetation. They feed mainly on mudflats and the intertidal zone (Khabali et al., 2011; Masero et al., 2000).The intertidal zones and vegetated areas are more extensive in Merja Zerga than in the urbanized wetlands of Oued Martil and Oued El Maleh. This physical difference results in an ecological difference, with a greater abundance of shorebird species at Merja Zerga. Regarding 11 families of waterbirds, studied wetlands hosted fewer than six species (Figure 6b).

In 3 families, the urban wetlands contained the same number of species as the Ramsar site: *Phoenicopterus roseus* (Phoenicopteridae); *Ciconia ciconia* (Ciconiidae); *Plegadis falcinellus* (Threskiornithidae) and *Platalea leucorodia* (Threskiornithidae) (Figure 6b, Figure 7a). Urban wetlands holded more Laridae (14 and 11) than Ramsar site (13); and less species in Ardeidae (5 and 6) and Rallidae (3 and 4) families than Ramsar site merja Zerga (9 and 7). Laridae are generalist species and can adapt to human presence and urban landscapes. In contrast, most Rallidae and some Ardeidae need open water and vegetation to rest, to feed and to breed.

Within the functional group of Passerines, 13 families are present in the urban wetlands of Oued Martil and Oued El Maleh, as well as the Ramsar site Merja Zerga. Oued El Maleh and Oued Martil wetlands recorded fewer species in Muscicapidae(2), Motacillidae (3) and Fringillidae (1) than Merja Zerga (10, 9 and 6) (Figure 6a). Passerines occupy open spaces and avoid urban areas. Regarding Accipitridae, they are Raptors, and only a few species find suitable habitats in urban areas (3) in comparison to Ramsar site (8). Finally, urban wetlands and protected wetland host the same number of species across 9 families: Falconidae, Pandionidae, Sturnidae, Passeridae, Corvidae, Upupidae, Meropidae, Burhinidae, and Glareolidae (Figure

6c). Some common species are: *Falco naumanni, Merops apiaster, Upupa epops, Burhinus oedicnemus, Glareola pratincola, and Pandion haliaetus.*

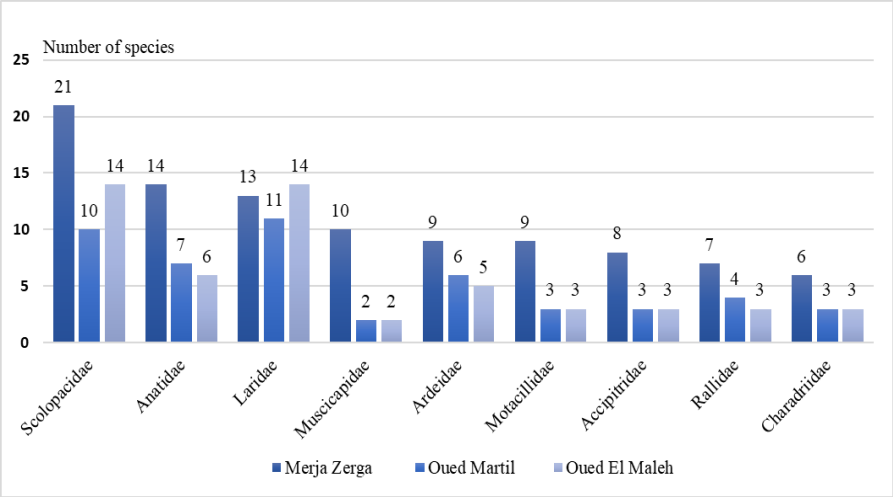

Figure 6a Comparison of bird families and species richness in the urban wetlands of Oued Martil and Oued El Maleh with the Merja Zerga Ramsar site. The Ramsar site hosts 1.5 to 2.5 more species than the urban wetlands.

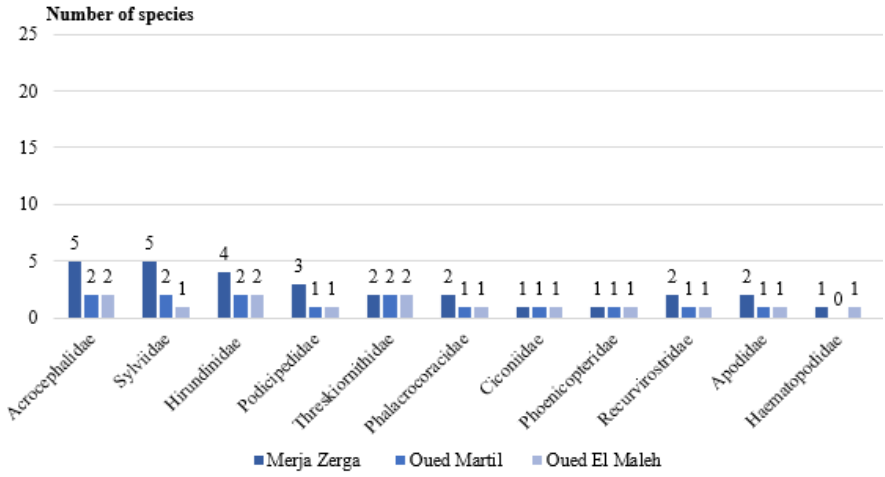

Figure 6b Comparison of species richness and waterbird families in the urban wetlands of Oued Martil and Oued El Maleh, and the Ramsar site Merja Zerga. Despite their differences, the three environments host the same number of species or the same species within the same families.

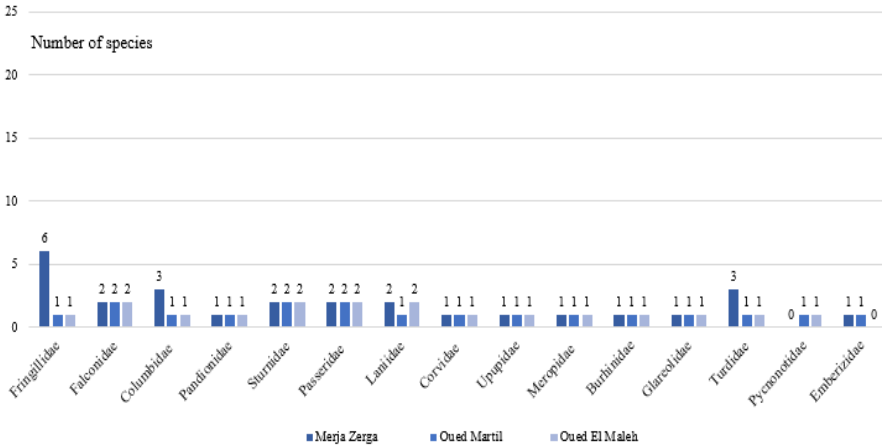

Figure 6c Comparison of species richness in selected families of passerines and waterbirds between the urban wetlands of Oued Martil and Oued El Maleh, and the Ramsar site Merja Zerga. Several passerine species find suitable habitats in both the urban wetlands and the Ramsar site.

This comparaison show that, despite urban wetlands Oued Martil and Oued El Maleh have smaller size than the Ramsar site, are unprotected while Merja Zerga was designated for many protection statuses, there are significant ecological similarities between these ecosystems. Even the urban wetlands of Oued Martil and Oued El Maleh are higly urbanized, it support various avian groupes, families and species, and many are common with the Ramsar site. It can be related to the fact that urban wetlands and the Ramsar site are coastal and probably offer both saltwater and freshwater habitats, halophilic and hygrophilic vegetation, coastal intertidal zones, and open water surfaces (Day et al., 2021). In the other hand, Arslan et al. (2025) found that landscape type has a distinct influence on bird communities, driven by species habitat specialization and urban areas are dominated by generalist species, while we found that specialist species (Passerines, Waders, Anatidae, Rallidae) can be hold by urban wetlands in less number; and generalist species (Gulls, some Ardeidae) can find urban areas suitables. In urbanized areas, wetlands play a role in supporting bird communities, including species not typically associated with wetland environments (McKinney et al., 2011) like Passerines and Raptors.

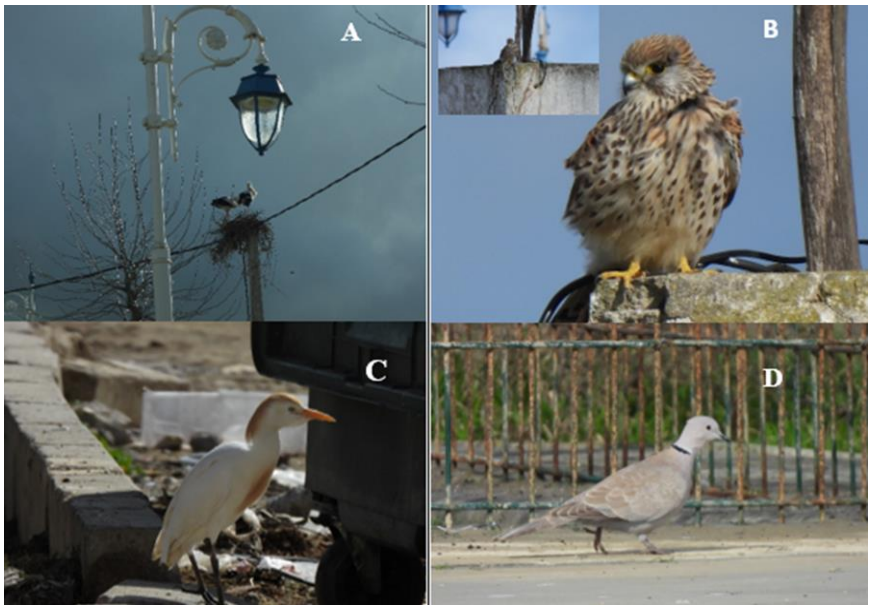

Figure 7a Some bird species benefit from the urbanization of the wetland ecosystems of Oued Martil and Oued El Maleh. They have adapted to this anthropization in various ways: A: Ciconia ciconia (Ciconiidae) nests on urban buildings and human structures (Oued El Maleh); B: Falco tinnunculus (Falconidae) uses human buildings to hunt its prey (Oued El Maleh); C: Ardea ibis (Ardeidae) feeds on urban organic waste (Oued Martil); D: Streptopelia decaocto (Columbidae) is common to both the urban wetlands and the Ramsar site. It is well adapted to human presence and feeds in urban and suburban spaces (Oued El Maleh).

Urban wetlands of Oued Martil and Oued El Maleh holded one specie in the Columbidae family (*Streptopelia decaocto*), while Merja Zerga hosted three species (*Columba palumbus, Streptopelia turtur*, and *S. decaocto*). *Streptopelia decaocto*, which is common to all three wetlands, is well adapted to human presence and often feeds in suburban areas and agricultural land. It tends to approach human dwellings where food is readily available. The other two species are more wary and prefer habitats that are far from human activity (Bocher et al., 2014; Coombs et al., 1981). Another difference between the three wetlands is recorded in terms of species diversity within the functional group of Passerines (Figure 6c). Indeed, Merja Zerga has greater diversity in both families and species of Passerines (Order Passeriformes). Specifically, these differences concern 4 species from the Phylloscopidae family; 3 species from the Strigidae family; and two species from the Muscicapidae, Paridae, and Locustellidae families.

Moreover, 10 families of Passerines have been recorded exclusively at Merja Zerga, with only one species present for each family. These families are Oriolidae, Malaconotidae, Pycnonotidae, Troglodytidae, Cettiidae, Alcedinidae, Coraciidae, Phasianidae, and Gruidae, and they are represented by these species: *Oriolus oriolus, Tchagra senegala, Pycnonotus barbatus, Troglodytes troglodytes, Cettia cetti, Alcedo atthis, Coracias garrulus, Alectoris* barbara, and *Grus grus*.

The order Passeriformes (Passerines) is the largest in the class Aves (60% of living birds), comprising the highest number of species (around 6,000) in global avifauna (Rocha-Camarero & de Trucios, 2002). Commonly known as perching birds or songbirds, passerines rely on trees, forests, and well-developed riparian vegetation. The unique structure of their feet (three forward-facing toes and one backward-facing toe) allows them to grip branches effectively. Merja Zerga is an unurbanized wetland covering a large area (7,300 ha) (Merja Zerga | Ramsar Sites Information Service), has a surface covered with tall vegetation larger than urban wetlands, and provides various habitats suited to the lifestyle of Passerines.

The differences in species richness between urban wetlands and Ramsar site can be linked to variations in freshwater and saltwater supply, hydrological regimes, degree of urbanization and human impact, type of vegetation cover, and levels of human activity. Indeed, these factors are more pronounced in the urban and peri-urban wetlands of Oued Martil and Oued El

Maleh (Benmokhtar, 2023). Our findings highlighted that several species and families are common to urban wetlands and Ramsa site. These results suggest that these species move between the three areas and find similar habitats, food resources, and resting or migratory stopover sites in all three wetlands. Indeed, these wetlands are located along the East Atlantic flyway, which is important for the migration of tens of millions of birds each year.

Urban wetlands Oued Martil and Oued El Maleh recorded fewer bird species and families richness than the Ramsar site Merja Zerga (Table 1).This lagoon was included in the Ramsar Convention list in 1980, because it is important for wintering migratory waterbirds (Saguem et al., 2020). It is a biological reserve (Since 1978), an IBA Important Bird Area (Since 2001), a site of Biological and Ecological Interest SIBE (Since 1996) and a KBA Key Biodiversity Area (Since 2016) according to BirdLife International classification (Benmokhtar, 2023). Merja Zerga is the largest lagoon in morocco (Saguem et al., 2020) and have a large open water area (Ayache et al., 2009). Moreover, the wetland ecosystems of Oued Martil and Oued El Maleh are unprotected, highly urbanized and are smaller than Merja Zerga.They are highly fragmented, dominated by buildings, roads and are missing the dense and diverse plant cover habitats. Moreover, highly urbanized wetlands are poorer in these habitats (Taylor et al., 2021). Indeed, the urban and peri-urban wetlands of Oued Martil and Oued El Maleh have lost much of their vegetation (Figures 7b, Figure 7c). The multi-annual development of the Martil plain and the urbanization of the main channel of the Oued Martil have led to the degradation of the riparian forest. The bed of Oued El Maleh along the beach and coastal dune system is restricted to the minor bed, and one of its banks is in direct contact with the road connecting Martil to Tetouan and Cabo Negro. These developments and urbanization have resulted in the degradation of the riparian forest and the retreat of vegetative cover, which has led to a decrease in the species and families diversity in the urbanized wetlands of Oued Martil and Oued El Maleh.

Figure 7b Habitat transformation due to the accelerated urbanization of the Oued Martil wetlands: Human dwellings and buildings extend to the water's edge (A and B), and urban waste is found in these habitats. Synanthropic birds and generalist species adapt their behaviors to human presence and feed on urban waste. C: *Egretta garzetta* (Ardeidae), *Larus michahellis* (Laridae), and *Ardea ibis* (Ardeidae); D: *Ciconia ciconia* (Ciconiidae), *Ardea cineria* (Ardeidae), and *Ardea ibis* (Ardeidae).

3.2. Phenological Status

This study compared the phenological statuses of the bird species recorded in urban wetlands, Oued Martil and Oued El Maleh, and in the Ramsar site. The findings are that urban wetlands as well as protected wetland hosted several species with varying phenological statuses: Passage migrants (PM), Wintering visitors (WV), Resident breeders (RB), Migratory breeders (BM), Occasionnal wintering (OW), occasional breeders (OB), and species for which the wintering visitor status is not confirmed (Occasional wintering) (Bergier et al., 2022).

In this study, urban wetlands of Oued Martil and Oued El Maleh as well as the Ramsar site, host the most numerous species in following phenological statuses: Passage migrants (PM) and wintering visitors (WV). Furthermore, urban wetlands recorded the lowest number of species in each phenological status, about 1.75 to 3 times less species, than protected Ramsar

site Merja Zerga. Passage migrants are few in number in Oued El Maleh (58 PM) and Oued Martil (54 PM) than Merja Zerga (124 PM). Urban wetlands Oued El Maleh and Oued Martil hosted 66 and 25 wintering migrants, number that is smaller than 116 WV in the Ramsar site.

RB Resident breeders recorded in Urban wetlands are 44 and 32, wich is less important than 77 RB in Merja Zerga; 19 and 13 BM migratory breeders in urban wetlands is fewer than 40 BM in the protected wetland. The two studied urban wetlands recorded 13 OW occasional wintering, three times smaller than 36 OW in Merja Zerga. 8 OB occasional breeders are recorded in the urban wetlands and this record is less important than 17 OB in the protected wetland. Finally, 7 BM/RB breeder migrants and resident breeeders were observed in the urban wetlands and 9 BM/RB are recorded in the Ramsar site. (Figure 8). Three former breeders in Morocco, are recorded in urban wetlands and Ramsar site: *Phoenicopterus roseus, Gyps fulvus*, and *Milvus migrans.*

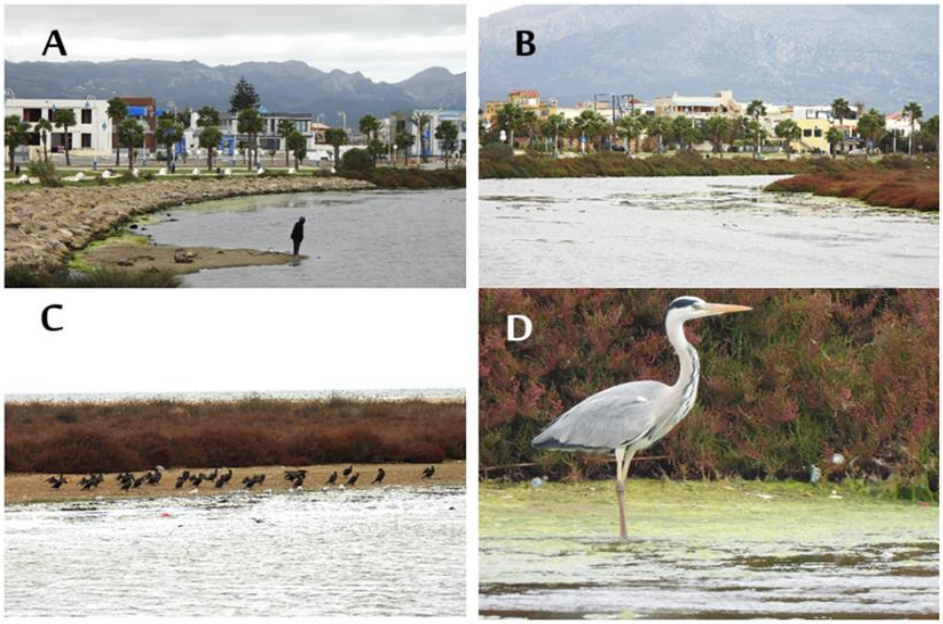

Figure 7c The urban wetland of Oued El Maleh is highly urbanized and lost the riparien forest. Human buildings and roads are near riparien vegetation cover and open water. Despite these transformations, bird species find habitats for resting, feeding ans resting in this urban ecosystem. C: *Phalacrocorax carbo* (Phalacrocoracidae) and several species of the Laridae (Gulls) and ; D: *Ardea cineria* (Ardeidae) find refuges for resting and feeding in riparian vegetation cover and open water.

Regarding this records, urban wetlands Oued El Maleh and Oued Martil, hold less PM, WV, RB, BM, OW and BM/RB than the Ramsar site Merja Zerga. On the other hand, urban wetlands holded a highest number of passage migrants, wintering visitors and resident breeders (Figure 8), which means that unprotected and urbanized wetlands are important for migratory, wintering and breeders avifauna.

Urban wetlands and Ramsar site are geographically located along the major East-Atlantic flyway. In addition, Urban wetlands of Oued Martil and Oued El Maleh are located in Northern Africa (Northern Morocco) and Southern Europe. Many bird species rely on these wetlands for migratory stopovers and wintering just before crossing the Mediterranean Sea (Britton & Crivelli, 1993; Bergier et al., 2022).

These phenological statuses highlight the important role of urban wetland ecosystems in the conservation of local and global avian biodiversity. Migratory species use these environments as a passage twice a year, wintering visitors need these wetlands during wintering period, and breeders may nest in. Urban wetlands provide habitats for migrant, wintering, resident and breeder avifauna. These results highlight the importance of urban wetlands in supporting avian biodiversity, as well as the protected wetlands, and align with the work of many other authors. In one hand, McKinney et al. (2011) found that small urban wetlands are important in the conservation of both local and global biodiversity. In the other hand, Hanford et al. (2020) found that urban wetlands can provide refuge for migratory birds.

Urban wetlands support less bird species in each phenological status compared to Ramsar site. This finding can be explained by the area of Merja Zerga, the largest lagoon in Morocco and the quality of its habitats even before the conservation. These results are in agreement with previous studies. The larger waterbird species biodiversity in Ramsar wetlands can be related to the fact that the designation of Ramsar sites was based on the presence and nesting of several aquatic birds (Fois et al., 2024). In addition, conservation targets biodiversity hotspots and conservation initiatives, taken after designation, may improve habitat conditions for waterbirds (Kleijn et al., 2014). On the other hand, urban wetland Oued El Maleh holded more specie number for each status than Oued Martil (Figure 8). It may be related to the differences in hydrological characteristics, food ressources availibilaty, vegetation cover and the higher urbanization of Oued Martil.

Studied urban wetlands have a smaller area, fragmented habitats, and are disturbed by human activities.They are located near other Ramsar sites in Northern Morocco and near the Gibraltar migratory passage. They are part of the sites the birds frequent twice a year. Migratory birds rely on ecosystems and their habitats, in protected, unprotected and urban wetlands, during their migration between Eurasia and Africa, after or before crossing the Mediterranean Sea. Mediterranean wetlands, along the East-Atlantic flyway, provide habitats for groups of species, including migratory and wintering waterbirds. Indeed, urban wetlands increase the biodiversity in urban areas by acting as networks of fragmented habitat to facilitate the movement of species in the environments (Alikhani et al., 2021).

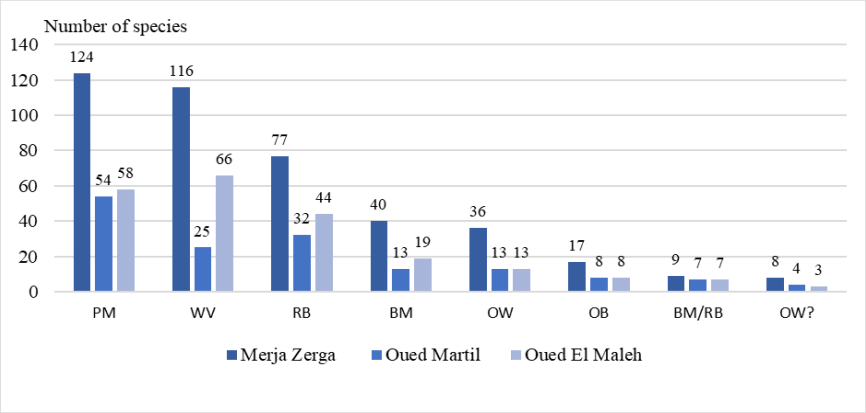

Figure 8 Phenological status of bird species in the urban wetlands of Oued Martil and Oued El Maleh, and the Ramsar site Merja Zerga (Northern Morocco). PM: Passage Migrant; WV: Winter Visitor; RB: Resident Breeder; BM: Breeding Migrant; OW:Occasional Winter occurrence of regular migrant species-BM,PM; OB: Occasional Breeder; OW? Possible Occasional winter.

Merja Zerga was designed as a Ramsar site due to its biological and ecological qualities and international importance for biodiversity and birds, especially wintering and migratory birds. It was also designated as an IBA site (Magin, 2000; Benmokhtar, 2023). We found that the Ramsar site hosted a richer biodiversity in terms of the number of families and species, and a high number of passage migrants and wintering visitors.

In addition, to our knowledge, urban wetlands Oued El Maleh and Oued Martil were not studied or monitored before and the only data available to us are those obtained during this research work. Merja Zerga is the most studied wetland in Morocco and the data is abundant. Furthermore, the references for urban wetlands are updated (Mars et al., 3023a; Mars et al., 3023b) while those for Ramsar site are old (Cherkaoui et al., 2007).

It is interesting to carry out more studies in urban wetlands Oued El Maleh and Oued Martil and recent monitoring in Ramsar site Merja Zerga. It would be more interesting to examin the characteristics of wetland areas such as water level and the nature of the vegetation cover, the temporal changes in species richness and bird abundance, the functional diversity, and bird community assembly.

3.3. Conservation Status

The urban wetlands of Oued Martil and Oued El Maleh hosted a remarkable and patrimonial avian species, vulnerable, endangered, and declining species according to the IUCN, as well as the Ramsar site Merja Zerga (Table 2). We found that urban wetlands are used by the same vulnerable species based on IUCN criteria, the same species declining in Morocco, and the same species considered endangered in Morocco. Most of these common species have a decreasng population Globally, in Europe or in Morocoo. Conservation statuses in Europe, in Mediterranean region and globally IUCN statuses are recorded accordins the IUCN Red List of Threatened Species from 2012 to 2024 (https://www.iucnredlist.org/). The Moroccan status is deteminated according a work of Birdlife International done by El Agbabi et al. (2011) and Bergier et al. (2022).

Table 2 Conservation Status of Bird Species in the Urban Wetlands of Oued Martil, Oued El Maleh, and in the Ramsar Site of Merja Zerga : VUL IUCN: Vulnerable according to IUCN criteria; ENDANG Mo: Endangered in Morocco;ENDEC Me: In decline in the Mediterranean; ENDEC Mo: In decline in Morocco; ENDEM Mo Subsp: Species with endemic Moroccan subspecies; ENDEM Ma Subsp: Species with endemic subspecies of the Maghreb; ENDEM My Taxon?: Taxon potentially endemic to the Maghreb.

Conservation status	Oued Martil	Oued El Maleh	Merja Zerga
VUL UICN	7	7	7
ENDANG Mo	6	5	6
ENDEC Me	2	2	2
ENDEC Mo	2	2	2
ENDEM Mo SubSp	5	5	7
ENDEM Ma Subsp	8	8	9
ENDEM Ma Taxon ?	1	1	2

We can highlight some species: *Aythya nyroca* is endangered in Morocco and near Thretened Globally; *Fulica cristata* is Critically Endangered in Europe and vulnerable in Morocco; *Nycticorax nycticora*x and *Netta rufina* are Vulnerable in Morocco; *Larus audouinii* is Vulnerable in Europe and globally, and vulnerable as a breeder in Morocco; *Marmaronetta angustirostris* is Vulnerable in Europe and Near Threatened globally and endagered in Morocco; Mareca strepera and Spatula clypeata are declining in the Mediterranean region;

In the other 8 families, Merja Zerga contained more species with heritage and remarkable species, such as: Anas crecca, A. anser, A. acuta, Rallus aquaticus, Crex crex, Calidris temminckii, Tringa erythropus, T. nebularia, Limosa lapponica, Pluvialis apricaria, P. squatarola, Stercorarius pomarinus, Elanus caeruleus, and Circus pygargus (El Agbani et al., 2011; Bergier al., 2022), due to its hydrological, sedimentary, and vegetative characteristics.

The urban wetlands of Oued Martil and Oued El Maleh hosted five species with subspecies endemic to Morocco (*Galerida theklae, Galerida cristata, Curruca melanocephala, Phalacrocorax carbo,* and *Motacilla alba*)—compared to seven at the Ramsar site of Merja Zerga. *Galerida theklae* has been recorded exclusively in the urban wetlands. Species such as Asio capensis, Alectoris barbara, and Phalacrocorax aristotelis have been observed at Merja Zerga. The subspecies *Motacilla alba sp. supersonata* (Moroccan Wagtail) is endemic to Morocco and is identified with Motacilla alba sp.alba, in the urban wetlands. Eight species (compared to nine at Merja Zerga) with subspecies endemic to the Maghreb have been observed in the wetland ecosystems of Oued Martil and Oued El Maleh (Galerida theklae, G. cristata, Pycnonotus barbatus, Alauda arvensis ,*Passer domesticus, Turdus merula* and *Lanius excubitor*). Among these, three species have not been recorded at Merja Zerga (*Galerida theklae, Alauda arvensis,* and *Lanius excubitor*). A potentially endemic taxon is represented by one species in the Oued Martil and Oued El Maleh wetlands, whereas it is absent from Merja Zerga. These potentially endemic taxa are represented by one species (*Lanius excubitor*) in the urban wetlands and by two species at the Ramsar site of Merja Zerga (*Troglodytes troglodytes* and *Fringilla coelebs*).

These findings highlight the importance of urban and small wetland areas for bird species, and the need to consider their designation and protection in order to safeguard Moroccan, Mediterranean, and global biodiversity. Further studies are necessary to confirm the level of endemism in these wetlands and to better understand the diversity of their bird populations. Urban wetlands can provide refuge for threatened and migratory fauna (Hanford et al., 2020), provide refuge for less ubiquitous or more disturbance-sensitive species, making them important for conservation efforts in cities (McKinney et al., 2011). According these results, it's essential to support the inclusion of wetlands in urban land-use planning and conservation development strategies, in order to protect avian diversity and ecological functions in cities (McKinney et al., 2011), and contribute to the conservation of endangered species (Alikhani et al., 2021).

3.4. Impact of Urbanization on Wetlands

Urbanization affects both terrestrial and aquatic ecosystems (Ghosh & Pal, 2023; Taylor et al., 2021) and human activities lead to modifications in habitat structures. The urban development of the Martil plain and the intense urbanization have transformed the foodplains of Oued Martil and Oued El Maleh. Urbanization is recognised as a significant cause of wetland loss (Panuccio et al., 2017). Not only can urban development cause destruction of wetlands, but it often also alters hydrological cycles, increases pollution that transforms wetlands, and influences species composition and species diversity (Ehrenfeld, 2000). Some bird species are unable to adapt to these changes or to the presence of humans, while others succeed through various strategies.

Synanthropic birds and generalist species adapt their behaviors to human presence and benefit from the urbanization of the wetland ecosystems. Ciconia ciconia (Ciconiidae) nests on urban buildings and human structures and feeds on urban waste; Falco tinnunculus (Falconidae) uses human buildings to hunt its preys ; Streptopelia decaocto (Columbidae) is common in urban areas and wetlands, is well adapted to human presence and feeds in urban and suburban spaces; *Egretta garzetta* (Ardeidae); *Larus michahellis* (Laridae), and *Ardea ibis* (Ardeidae); *Ardea cineria* (Ardeidae) feed on urban waste (Figure 7a; Figure 7b)

These observations highlights the adaptability of some species to urban environments. However, some emblematic and heritage species, such as *Fulica cristata*—classified as vulnerable by the IUCN and endangered in Morocco and is listed as Critically Endangered; was observed among solid waste in degraded environments.

The urban wetland of Oued El Maleh is highly urbanized and lost the riparien forest. Human buildings and roads are near riparien vegetation cover and open water. Despite these transformations, bird species find habitats for resting, feeding ans resting in this urban ecosystem. *Phalacrocorax carbo* (Phalacrocoracidae), several Laridae (Gulls) and *Ardea cineria* (Ardeidae) find refuges for resting and feeding in riparian vegetation cover and open water (Figure 7c). In fact, urban constructions can even be used by certain bird species, such as *Sturnus unicolor* and *Plegadis falcinellus*. Sturnus unicolor is well adapted to human presence and constructions; and *Plegadis falcinellus* was observed foraging in urban gardens (Figure 9a).

Many species adapted to urbanization are found in open water and in riparian vegetation such as this population of *Spatula clypeata* and *Aythya ferina* and *Gallinula chloropus* (Figure 9b). We previously documented an important reproduction

of many bird species, including Anatidae and remarkable species (Mars et al. 2023a; Mars et al. 2023b) in studied urban wetlands.

Figure 9a Bird population in urban wetlands, Oued Martil and Oued El Maleh, highly transformed by rapid urbanization.A: Sturnus unicolor is well adapted to human presence and constructions; B: *Fulica cristata* surrounded by urban waste; C: Population of *Fulica atra* and *Fulica cristata*, along with Anatidae and Laridae, near human constructions (Dizza neighborhood) in Oued Martil.; D: *Plegadis falcinellus* foraging in urban gardens.

Figure 9b A,B: Urban wetland Oued Martil is highly transformed by urbanization. Residential buildings and roads are situated near wetland habitats. Many species have adapted to this urbanization. They are found in open water and in riparian vegetation such as this population of *Spatula clypeata* and *Aythya ferina* (C) and *Gallinula chloropus* (D).

Urbanization poses challenges (Livingston, 2020) for bird species, as they suffer the negative effects of human activities. Some waterbirds, such as *Fulica atra, Fulica cristata*, species of Anatidae and Laridae, are found near humans and their constructions. The presence of these remarkable and heritage species in urban areas raises questions about management and conservation policies. It becomes necessary to reconsider the restoration and conservation of wetlands in light of these changes.

Many synanthropic bird species in urban wetlands and urban area can exploit the resources of anthropogenic origin found in the city for both nesting and feeding purposes.They have adapted to live in highly anthropized habitats, well tolerating the anthropogenic pressure and activities (Coccon et al., 2022). Regarding the impact of urbanization, we noted the presence of solid waste, the destruction of vegetation, human activity, and the proximity of construction work affecting bird habitats, even during the breeding season. We also observed the presence of more species that tolerate human presence or exploit urbanized habitats. Urbanization leads to changes in hydrological functions, the water cycle, habitat fragmentation, biodiversity erosion, and threatens the socio-cultural heritage of local populations (Datri et al., 2024).

Despite their high urbanization, urban wetlands Oued Martil and Oued El Maleh provide habitats for various avian species and especially waterbirds. Similar patterns was obseved by McKinney et al. (2011) who compared urban wetlands, rural wetlands and uplands. They found that bird abundance and species richness are higher in wetlands than upland sites, and that avian species richness can be higher in urban wetlands than rural wetlands and uplands, if urban wetlands provide food ressources (fruits, Insectes, Macroinvertebra), refuge, nesting and resting sites. In addition, urban wetlands support avian biodiversity and facilate the movment of species in urban environments even when species richness decrease from non-urbanized to urbanized sites (Alikhani et al., 2021).

Urban wetlands Oued Martil and Oued El Maleh and Ramsar site Merja Zerga are natural wetlands and not constructed and not man-made. As a protected wetland and a largest lagoon in Morocoo, Merja Zerga is the most studied wetland. In contrast, we didn't find many ornithological studies for urban wetlands Oued Martil and Oued El Maleh. High urbanization and rapid development transformed these wetlands. It is clear they are important for local and global bird biodiversity. More studies and regular monitoring are necessary to evaluat losses in urban wetlands and their implications (Green et al., 2021).

Despite their importance for waterfowl and aquatic plants (Green & Elmberg, 2014), few wetlands benefit from protection and/or classification. Urban wetlands are not considered significant by most researchers, and it is only recently that some studies have begun to focus on these important ecosystems in urbanized areas (Alikhani et al., 2021; Livingston, 2020).

Urban wetlands interact with various parameters, including population growth and density, urban development, urbanization, sustainability, and help by improving health and well-being, bringing biodiversity to cities and cannot be replaced by other urban ecosystems (Alikhani et al., 2021).

4. Conclusions

The main findings of this study highlight the differences and similarities between the urban wetlands of Oued Martil and Oued El Maleh and in the Ramsar site of Merja Zerga, in terms of species and families diversity, the phenological and the conservation statuses of bird species. Although Merja Zerga exhibited higher avian richness in terms of the number of species and families compared to the urban wetlands of Oued Martil and Oued El Maleh, the latter also harbor a remarkable diversity of species. The phenological statuses and conservation statuses of the species are noteworthy across the three sites. However, urbanized wetlands, despite the anthropogenic pressure they face, they still preserved remarkable and heritage bird species in addition to migratory, wintering, and breeding populations. The studied wetlands are coastal and exhibit some distinct ecological characteristics as well as similarities. These characteristics may be linked to their geographical location near the Strait of Gibraltar and their attractiveness as migratory stopover sites. These observations highlight the importance of conservation and differentiated management of these sites based on their specific characteristics and the species they host. Urbanization exerts a significant impact on wetlands, leading to changes in species diversity. Nevertheless, some species adapt well to these modified environments, highlighting the importance of urban wetlands as alternative habitats for birdlife. While species diversity may decline, urban wetlands continue to support remarkable species. They are essential as refuges for avian biodiversity in urbanized environments. In summary, urban wetlands exhibit different species diversity and conservation statuses compared to natural sites like Merja Zerga, yet they remain valuable ecosystems for the conservation of birdlife and the maintenance of local and regional biodiversity. Their location and their role as wintering sites, migratory stopover sites, and breeding sites demonstrate the need for their protection, conservation, and appropriate management. This conservation is crucial for biodiversity in general and for Moroccan, Mediterranean, and global avian biodiversity. Adapted management plans are necessary in the context of increasing urbanization, climate change, and water scarcity in Morocco and the southern Mediterranean coast.

Ethical considerations

The wellfare of the observed birds is not compromised, neither during nesting nor during the rest of their life cycle.

Conflict of Interest

The authors declare no conflicts of interest.

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