Close to the Madding Crowd: How Resilient are Imperilled Mediterranean Urban Wetlands?

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Abstract

Investigating how Mediterranean wetlands respond to adjacent land use conversion, is an important first step in mitigating the impact of human encroachment and other environmental stressors. We monitored the composition and structure of waterbird assemblages, in a Mediterranean urban marsh, subjected to severe anthropogenic pressures. Remote sensing indicated that in the last two decades Boussedra Pond was subjected to landfill, resulting in a substantial reduction (~ 50%) of the marsh, while due to a lack of urban planning urban built-up and agriculture areas expanded considerably in its surroundings. Seasonal changes in the diversity of waterbirds, including the globally Endangered (EN) White-headed Duck *Oxyura leucocephala* and the Near-Threatened (NT) Ferruginous Duck *Aythya nyroca*, reflected the importance of the site as a staging and wintering area for many migratory species. The long-term study also suggested that breeding waterbirds species respond differentially to the loss and degradation of habitats, as highlighted by the resilience of the synanthropic Moorhen *Gallinula chloropus* and the disappearance of several breeding marsh specialists, like the Little Bittern *Ixobrychus minutus* and the Western Marsh Harrier *Circus aeruginosus*. The study points out the need for both a coordinated cross-sectorial land use planning and an immediate, affordable and sustainable wetland conservation action.

1. Introduction

The world may have lost up to 87% of its wetlands over the last three centuries, with the twentieth century accounting for over 50% of this loss (Davidson 2014). Wetland loss and impairment of wetland functions deprives human communities of vital ecosystem services and is a driver of biodiversity erosion (O'Connell 2003). Moreover, because wetlands sequester about 12% of the global carbon pool and play key roles in biogeochemical fluxes between the lithosphere, hydrosphere and atmosphere, their loss contributes significantly to climate change (Sahagian and Melack 1998; McInnes 2018). Thus, wetland loss is a global environmental problem and assessing the root causes of their destruction may help develop adaptation measures and increase their resilience to anthropogenic stressors (Erwin 2009).

The Mediterranean basin qualifies as one of the global biodiversity hotspots hosting a high proportion of endemic species (Myers et al. 2000). This region also represents about 1.5% of the global wetlands area (Perennou et al. 2012). Unfortunately, Mediterranean wetlands are among the most threatened ecosystems, and are facing major habitat loss due to various anthropogenic stressors (Britton and Crivelli 1993; Cuttelod et al. 2008). For instance, over the 20th-century, loss of Mediterranean wetlands estimated at about 50%, affected waterbirds and other organisms which depended on wetlands habitat (Perennou et al. 2012).

Although drivers of wetland loss and degradation can vary widely between regions, agriculture and urban development have emerged as the main proximate causes (Asselen et al. 2013; Ricaurte et al. 2017). However, agriculture and urbanisation are major sources of water pollution releasing nutrients, pesticides and other contaminants into adjacent wetlands and contributing to a marked decline of biodiversity (Schreinemachers and Tipraqsa 2012; Benslimane et al. 2019). The expansion of agriculture is mainly driven by low-income people, who live in suburban areas but still rely on cultivated crops as financial assets. Encroachment and pollution may push wetland degradation beyond a critical threshold, leading to a loss of ecosystem services, species extinction and public health issues (Pedersen Zari 2014).

Algeria hosts a diversity of wetland types including freshwater and hypersaline lakes, ponds, brackish marshes and lagoons, with several sites recognized as Important Bird Areas(IBA) and Ramsar sites (Coulthard, 2001). These wetlands are crossed by three migratory flyways enabling north-south connectivity of Palearctic-African birds, thus providing important sites as stopover, wintering and breeding areas for several waterbird species (Samraoui and Samraoui 2008). In northeast Algeria, the Numidian wetland complex offers a mosaic of freshwater and brackish wetlands of great ornithological importance, including Boussedra, an important breeding and urban wintering site for waterbirds species (Samraoui et al. 2013, 2015).

Algeria is one of the contracting parties to the Ramsar Convention of 1971, the first international treaty that recognizes the interdependence of people and their environment (Finlayson et al. 2011). Consequently, the Ramsar treaty promotes the sustainable use of wetlands as « natural infrastructure » (Ramsar Convention Secretariat 2013). However, the assignment of a wetland as a Ramsar site, does not always confer effective protection or insure its rational management (Ayaichia et al. 2017). Although Algeria has designated fifty wetlands as Ramsar sites, many other wetlands, some classified as IBAs lack formal protection (Samraoui and Samraoui 2008). Boussedra Pond is one of those IBAs that has been neglected so far.

Urban ponds represent valuable wetland ecosystems (Boyer and Polasky 2004; Hill et al. 2016). As such, Boussedra Pond represents a typical case of a fragmented wetland where a lack of urban planning of its surroundings has allowed urban growth and human encroachment to cause an estimated decrease of 30 % of its initial area (Samraoui et al. 2012). This marsh is mostly known for its waterbird community, whose composition and population dynamics are strongly affected by several environmental factors such as wetland size, vegetation structure, water depth, water level fluctuations, and salinity (Benassi et al. 2007; Ma et al. 2010; Ramírez et al. 2018). In addition, human disturbances like hunting adversely influence the waterbird community (Madsen and Fox 1995; Paillisson et al. 2002). Therefore, the responses of waterbirds to environmental changes and human pressures make these species useful bioindicators for assessing the ecological status of wetlands (Amat and Green 2010; Green and Elmberg 2014). Furthermore, several waterbird studies have been conducted at Boussedra Pond (Samraoui et al. 2012, 2013; Meziane et al. 2014). These studies may serve as baseline knowledge to monitor species' response in the face of anthropogenic disturbances, like urbanization and agriculture intensification.Thus, there is a need for repeated waterbird surveys and monitoring their breeding ecology.

This study aimed at: (1) measuring the extent of habitat loss of this urban marsh, (2) identifying the drivers of habitat loss and degradation of Boussedra Pond, and (3) testing whether the effects of anthropogenic impacts on this urban marsh affected the composition, status and temporal patterns of its waterbird community by comparing present and past studies.

2. Materials And Methods

2.1. Study area

This study was conducted at Boussedra Pond (36°50'52.1" N, 7°43'37.6" E), an unprotected freshwater marsh surrounded by urban areas, located in the town of El Bouni in north-eastern Algeria (Figs. 1 and 2).This marshis characterised by a vegetation cover made up of Lesser Bulrush *Typha angustifolia* and Tamarisk *Tamarix gallica* (Samraoui et al. 2013). Boussedra Pond is an important breeding and wintering site for several endangered waterbirds like White-headed Duck *Oxyura leucocephala* and Ferruginous Duck *Aythya nyroca*, which led to its designation as an IBA (Samraoui and Samraoui 2008). Unfortunately, due to anthropogenic pressures like landfill, urban expansion, and wastewater discharge, the marsh has, over the last two decades, lost approximately a third of its initial surface area (Samraoui et al. 2012).

The field studies were conducted in accordance with national legislation.

2.2. Land use and land cover change monitoring

Images obtained from the Landsat 5 TM (for the years 1984 and 1998), Landsat 7 ETM (2008) and Landsat 8 OLI/TIRS (2018), were classified by Earth Observation Tools using the open-source QGIS environment (with a 1 km buffer zone), in order to produce land use and land cover (LULC) information. The Semi-Automatic Classification Plug-in (SCP) was used to generate training areas ROIs for each class, and then a classification was carried out using the Minimum Distance method based on the spectral signatures of the training areas. These latter areas were selected based on the different Landsat images in combination with high resolution images (Google Earth) and fieldwork. The resolution was 30 meters for the years 1984 and 1998 (Landsat 5) and 15 m for the years 2008 and 2018 (Landsat 7 & 8). Because the study area was relatively small compared to the resolution, we did not assess the precision of the classification. Thus, « validation » was carried out through observation and fieldwork experience.

2.3. Waterbird surveys

A waterbird survey was conducted twice a month from January 2019 to December 2019, using a 20 x 60 Optolyth telescope. Two observation points were chosen according to their accessibility and general vision of the site. For each observation, waterbird species were identified, and a direct count was made when the species abundance did not exceed 200 individuals, otherwise, an estimation was made by dividing the population into equal blocks of 20 individuals and taking the sum of the blocks (Bibby et al. 1998; Meziane et al. 2014). From mid-April to June, nest surveys were carried during the breeding season to identify breeding species and determine their phenological status. We also made use of a database based on long-term studies of the breeding ecology of waterbirds and spanning the years 2002–2008 (Samraoui and Samraoui 2008; Samraoui et al. 2011, 2012, 2013, 2015).

2.4. Data analysis

In order to analyze the diversity and structure of the waterbird community, the following ecological parameters were calculated: species richness (R): the number of species recorded in each survey, abundance (N): number of individuals counted for each species, and relative abundance (RA): explained by the proportion of a species abundance compared to the total abundance of all species $RA = (n/N) \times 100$. We also calculated the Shannon-Wiener index, expressed by the function $H' = -\sum_{i=1}^{S} pilnpi$, where S is the number of species and pi is the proportional abundance of species i in the community, and the Evenness index $E = H'/Hmax$, which is the ratio of the Shannon index (H') to the maximum value that this index could reach *Hmax, where* $Hmax = ln\ S$ (Magurran 1988). Multivariate analysis was performed using Principal Component Analysis (PCA) based on bird census, (species × months) with seasons used as a supplementary variable to explore the seasonal variation. PCA is an unsupervised learning method which reduces the dimensionality, represents and visualizes large data sets using a smaller number of variables (components which retain most of the data set's information) (Jolliffe 2002). Prior to the use of PCA, we run Bartlett's test of sphericity which checks whether the correlation matrix of the data set is significantly different from an identity matrix. All statistical analyses were performed using the R software (R Development Core Team 2019).

The spatiotemporal dynamics of land use and land cover (LULC) in and around Boussedra Pond (with a 1 km buffer zone), showed that between 1984 and 2018, significant land conversions had occurred (Fig. 3). Outside Boussedra Pond, the built-up areas more than doubled in size (+ 148%). Similarly, during the same period, agricultural areas doubled in extent (+ 100.3%). These two expansions were carried out at the expense of natural terrestrial vegetation, which lost 77% of its initial range. Boussedra Pond also underwent extensive changes, with landfill occupying almost 50% of the total marsh area by 2018. This expansion mirrored the concomitant loss of water and aquatic vegetation within the marsh (Table 1, Fig. 3).

Table 1
Surface area (m^2) and percent changes in brackets in landscape featuresbetween 1984 and 2018

	1984	**1998**	**2008**	**2018**
Inside				
Total area of the pond	467 411.0 (100)	467 411.0 (100)	467 411.0 (100)	467 411.0 (100)
Landfill	34 129.7 (7.3)	124 631.5 (26.7)	147 495.7 (31.6)	222 952.1 (47.7)
Tamarix gallica	13 959.8 (3.0)	10 744.0 (2.3)	9 971.4 (2.1)	4 319.0 (0.9)
Water + aquaticvegetation	419 321.6 (89.7)	332 035.8 (71.0)	309 944.2 (66.3)	240 139.5 (51.4)
Outside				
Total area outside of the pond	6 600 548.1 (100)	6 600 548.1 (100)	6 600 548.1 (100)	6 600 548.1 (100)
Built-up	1 322 202.9 (20.0)	2 140 209.1 (32.4)	2 638 919.3 (40.0)	3 283 985.0 (49.8)
Water	27 743.2 (0.4)	27 743.2 (0.4)	27 237.7 (0.4)	22 755.2 (0.3)
Natural terrestrialvegetation	4 072 595.2 (61.7)	2 682 832.6 (40.6)	1 701 699.8 (25.8)	934 019.4 (14.2)
Agriculture	1 178 006.8 (17.8)	1 749 763.2 (26.5)	2 232 690.7 (33.8)	2 359 788.5 (35.8)

The waterbird community was represented by 29 species belonging to 11 families, of which nine were wintering species, and 15 were resident breeders. In addition, five were passage migrants (Table 2). Anatidae and Ardeidae were the dominant families with 11 and four species, respectively. Species richness ranged from a maximum of 23 species recorded at the end of November to a minimum of 12 species recorded in August, with a significant decrease from May to August.

Table 2

Diversity, migratory status and relative abundance of waterbirds at Boussedra Pond (Samraoui and Samraoui 2008). (RB) = Resident Breeder, (WW) = Wintering Waterbirds, (PM) = Passage Migrants. The status of Threatened and Near Threatened species is presented in bold (BirdLife International 2020).

Common Name	Scientific Name	IUCN Red List	Relative Abundance (%)	Annual mean Abundance Mean ± SD	Phenological Status
Mallard	*Anas platyrhynchos*	LC	4.3	32.2 ± 14.6	RB
Gadwall	*Anas strepera*	LC	0.7	7.6 ± 10.7	WW
Common Teal	*Anas crecca*	LC	2	23.6 ± 28.4	WW
Northern Shoveler	*Anas clypeata*	LC	11.1	130.7 ± 127.3	WW
White-headed Duck	*Oxyura leucocephala*	EN	17.8	163.5 ± 91.1	RB
EurasianWigeon	*Mareca penelope*	LC	0.6	7.0 ± 8.7	WW
Northern Pintail	*Anas acuta*	LC	0.5	6.3 ± 8.3	WW
Garganey	*Spatula querquedula*	LC	< 0.1	0.2 ± 0.6	PM
Ferruginous Duck	*Aythya nyroca*	NT	4.4	36.3 ± 19.5	RB
Common Pochard	*Aythya ferina*	VU	1.8	21.3 ± 22.5	WW
Tufted Duck	*Aythya fuligula*	LC	< 0.1	0.2 ± 0.6	WW
Common Coot	*Fulica atra*	LC	9.3	71.7 ± 21.7	RB
Common Moorhen	*Gallinula chloropus*	LC	8	67.9 ± 21.4	RB
Purple Swamphen	*Porphyrio porphyrio*	LC	1.5	12.4 ± 6.5	RB
Black-necked Grebe	*Podiceps nigricollis*	LC	0.1	1.3 ± 3.0	PM
Great Crested Grebe	*Podiceps cristatus*	LC	0.8	5.8 ± 3.7	RB
Little Grebe	*Tachybaptus ruficollis*	LC	3.1	25.3 ± 13.6	RB

Common Name	Scientific Name		Relative Abundance (%)	Annual mean	Phenological Status
		IUCN Red List		Abundance	
				Mean ± SD	
Black-winged Stilt	*Himantopus himantopus*	LC	7.2	56.8 ± 36.3	RB
White Stork	*Ciconia ciconia*	LC	0.2	1.4 ± 2.0	RB
Little Egret	*Egretta garzetta*	LC	< 0.1	0.1 ± 0.3	RB
Cattle Egret	*Bubulcus ibis*	LC	12.6	92.4 ± 65.2	RB
Black-crowned Night Heron	*Nycticorax nycticorax*	LC	1	4.5 ± 15.6	RB
Eurasian Bittern	*Botaurus stellaris*	LC	< 0.1	0.1 ± 0.3	PM
Glossy Ibis	*Plegadis falcinellus*	LC	0.7	4.6 ± 7.7	RB
Yellow-legged Gull	*Larus michahellis*	LC	1.8	24.3 ± 46.0	PM
Black-headed Gull	*Larus ridibundus*	LC	10.1	145.1 ± 246.2	PM
Spotted Redshank	*Tringa erythropus*	LC	0.1	0.7 ± 1.4	WW
Common Redshank	*Tringa totanus*	LC	0.1	0.8 ± 1.4	WW
Western Marsh-harrier	*Circus aeruginosus*	LC	0.2	1.7 ± 0.5	RB

Total abundance of waterbirds oscillated between a maximum of 1733 individuals, recorded in January and a minimum of 422 individuals in June. The most abundant families were Laridae, Anatidae and Rallidae with peaks of 862, 705 and 232 individuals, respectively. These three abundance peaks were all registered in winter. At the species level, White-headed Duck, Cattle Egret *Ardea ibis* and Northern Shoveler *Anas clypeata* were the dominant species with an annual relative abundance of 17.76%, 10.3% and 11.13%, respectively. Shannon and Evenness indices fluctuated in concert, with maximum values of H' = 2.72 and E = 0.89 in November and October, respectively. The minimum values of H' = 1.57 and E = 0.66 were recorded in January.

The Bartlett's test of sphericity indicated that the correlation matrix used was suitable for factor analysis (p = 2.22e-16). The PCA showed a seasonal pattern, where species and family were subdivided into four groups according to their seasonal occurrence. The first two principal components were sufficient to account for 67.5% of the total variance (Fig. 4). The first component, which explained 43.1% of the total inertia, opposed species that occur early in autumn at the beginning of September and were represented by Eurasian Wigeon *Anas penelope*, Northern Pintail *Anas acuta*, Common Teal *Anas crecca*, Gadwall *Anas strepera*, Common Redshank *Tringa totanus*, Spotted Redshank *Tringa erythropus*, Little Grebe *Tachybaptus ruficollis* and Yellow-legged Gull *Larus michahellis*, to species which occur inspring like White Stork *Ciconia ciconia* and Black-crowned Night Heron *Nycticorax nycticorax.*

Furthermore, the second component with 24.4% of the total variance, opposed wintering species, which occur with high abundance and reach their maximum during the period from January to March, such as White-headed Duck, Northern Shoveler, Common Pochard *Aythya ferina*, Black-headed Gull *Chroicocephalus ridibundus*, to summer species associated with summer months and occurring from June to August like Glossy Ibis *Plegadis falcinellus*, Ferruginous Duck, Purple Swamp-Hen *Porphyrio porphyrio*, Great-crested Grebe *Podiceps cristatus*, Garganey *Anas querquedula* and Cattle Egret.

The survey of breeding pairs led to the recording of 48 rallid nests. This total which included 20 Coot clutches, 26 Moorhen clutches, and only two Purple Swamp-Hen clutches was compared to data collected in 2005 and 2008 (Samraoui et al. 2012, 2013, 2015) (Table 3).

Table 3
Nest numbers of Common Coot, Moorhen, and Purple Swamp-Hen at Boussedra Pond in 2005, 2008, and 2018

Year	*Fulica atra*	*Gallinula chloropus*	*Porphyrio porphyrio*
2005	277	22	22
2008	156	43	9
2018	20	26	2

3. Discussion

The results indicated a significant shrinkage which halved Boussedra Pond due to a ceaseless landfill. This encroachment on the marsh adversely affected both the waterbody and the vegetation cover. Concomitantly, the terrestrial vegetation surrounding the marsh greatly declined, losing ground to built-up areas and agriculture, which proved to be the main drivers of land conversion around the marsh. As has happened elsewhere, a lack of coordination between different governmental agencies, and an absence of cross-sectorial land-use planning, led to the unbridled expansion of urbanization and agriculture around a key wetland (de Bélair and Samraoui 1994; Panuccio et al. 2017; Benslimane et al. 2019).

The loss of terrestrial vegetation has important implications for the ecological integrity of the marsh (Stewart et al. 2016). Terrestrial vegetation harbours pollinators and pest predators, stabilises soil, and regulates climate by stocking carbon (Bolin 1977). Furthermore, terrestrial vegetation, close to wetlands, may also shelter nesting birds like Mallard *Anas platyrhynchos* (Fouzari et al. 2018). Aquatic vegetation also shelters breeding birds and other vertebrates as well as many invertebrates (Tscharntke 1992). In addition, waterlogged tamarisk trees are used for roosting and breeding by Cattle Egrets and other herons (Samraoui et al. 2007), whereas the alder carr at Lake Tonga hosts Ferruginous Duck's and Mallard's nests (Fouzari et al. 2015, 2018).

Similarly, helophytes are major habitats for breeding birds (Sutherland and Maher 1987; Samraoui and Samraoui 2007). For instance, both Mallard and Ferruginous Duck improve their nesting success in dense and high vegetation (Amat 1985; Fouzari et al. 2015). These findings support the importance of aquatic vegetation in providing food (Samraoui et al. 2015) and shielding nests from heat stress and predators, thus improving breeding success (With and Webb 1993; DeLong et al. 1995; Gandini et al. 1999; Jedlikowski et al. 2015).

The dominance of Anatidae in the waterbird community, is related to vegetation cover, where a foraging reliance on plants seeds is reported (Mouronval et al. 2007; Ayaichia et al. 2017), and to the availability of chironomids, tolerant to eutrophication in urban wetlands (Mackintosh et al. 2015), which constitute a crucial trophic resource for dabbling ducks (Sjöberg and Danell 1982), like Mallard (Street 1977; Batzer et al. 1993) and White-headed Duck (Green et al. 1999; Sanchez et al. 2000; Atiénzar et al. 2012). The recorded waterbird assemblages were characterised by a seasonal variation reflecting the changing functions of the marsh and its differential use by waterbirds.

Yet, despite its small size and the major anthropogenic changes that it has been undergoing, Boussedra Pond still harboured a great diversity of waterbirds, including the threatened White-headed Duck and Ferruginous Duck, by providing important habitats, and comparesfavourably with large Numidian wetlands that house a large array of habitats, such as Lake Tonga, Lac des Oiseaux, and Mekhada (Samraoui and Samraoui 2008; Samraoui et al. 2011). Peaks of richness and abundance values recorded in winter, reflected the importance of this site as a staging and wintering area for many migratory waterbirds.

Habitat loss and fragmentation is known to adversely affect biodiversity by causing marked population declines and extinctions (Kruess and Tscharntke 1994; Saunders et al. 1999). The lack or decrease in habitat heterogeneity may disrupt local extinction-colonization dynamics leading to regional species extirpation (Taylor et al. 1993; Hanski 1998), and previous studies focused on Mediterranean wetlands have shown the deleterious impact of fragmented wetlands on nesting birds (Paracuellos 2008; Battisti et al. 2008). In habitats altered by human activities, there is growing evidence of the existence of ecological traps and their adverse consequences for population dynamics (Battin 2004). As an altered environment, Boussedra Pond might act as an ecological trap if indirect cues used by birds to assess habitat quality mislead them (Hale and Swearer 2016). Similarly, human perceptions may lead to failed management objectives if knowledge gaps are not bridged on how birds respond to altered habitats (Hale et al. 2015). Thus, conservation planning requires a sound understanding of the relationship between cues for habitat selection and habitat quality (Kokko and Sutherland 2001).

Whereas the wintering waterbird assemblage was relatively diverse and appeared seemingly unaffected, the breeding assemblage provided a different account: one reedbed species, the Little Bittern,that regularly bred in Boussedra Pond went extinct. This species predominantly selects reedbeds as foraging and breeding habitats (Kushlan and Hancock 2005) but, as an area-sensitive species, it is known to be vulnerable to any reduction of its preferred habitat (Benassi et al. 2009). The Little Bittern managed to persist despite an initial loss of habitat of 30% (between 2003–2008). A further loss of 20% over the last ten years seems to have pushed the species over the edge. As human encroachment is fast destroying key wetland habitats, specialist species like Little Bittern, which occupy dense plant swards (Samraoui et al. 2012), are the most vulnerable, and their extinction may indicate a turning point in habitat loss, thus threatening further species (Semlitsch and Bodie 1998).

Another breeding reedbed specialist that went extinct in Boussedra Pond is the Marsh Harrier, a species that nests and forages in wetlands with dense and tall vegetation (del Hoyo et al. 1994). Poaching and wetland loss over the last two centuries have led to the decline of Marsh Harrier across its range, but reduced hunting pressures and wetland restoration has allowed the species to recover in Europe (Ferguson-Lees and Christie 2001). In contrast, the status of the Marsh Harrier in North Africa is poorly known, but the loss of key habitats is a source of concern.

A concomitant decline has accompanied the extinction of the Little Bittern and the Marsh Harrier,with two species of breeding Rallidae, the Coot and the Purple Swamp-Hen, all exhibiting a severe drop in breeding adults. The decline in the Rallidae also involved a regular passage migrant, the Little Crake *Porzana parva*, which has not been recorded at Boussedra Pond since 2008 (Samraoui and Samraoui 2008).

The Purple Swamp-Hen exhibited a gradual decline of breeding pairs since 2015. Although the species requires a lesser dense cover of vegetation, than Little Bittern and Moorhen, it relies more on plant swards for foraging, and may have special requirements in terms of plant stems and their nutrient content (Sanchez-Lafuente et al. 1998). Similarly, the Coot underwent a notable decline in breeding pairs when compared to previous surveys. It is known that the Coot rely strongly on the availability of reedbeds for nesting (Samraoui and Samraoui 2008), and thus it is likely that the drop of Coot nests can be explained by the large reduction of vegetation cover.

In sharp contrast and despite its heavy reliance on dense vegetation cover for nesting (Samraoui et al. 2013; Meniaia et al. 2014), the synanthropic Moorhen seemed more resilient than the Purple Swamp-Hen, because it manages to live in a wide range of habitats (ditches and canals), often in close proximity to humans (Samraoui and Samraoui 2008; Talbi et al. 2020). Thus, the shrinkage of the vegetation cover at Boussedra Pond did not seem to have adversely affected its breeding population, but further monitoring is required.

It is possible that these results are not applicable to all urban wetlands, but they confirm previous studies, which have shown that waterbirds respond differentially to decline of landscape features like area, edge effects and fragmentation (Báldi 1999; Paracuellos 2006). In particular, reedbed species are especially exposed to the degradation of their habitat, and their response may be used to assess the rapid deterioration of marshes and provide knowledge that may guide ongoing conservation efforts to mitigate the impact of human activities on wetland biodiversity (Ma et al. 2010; Davidson 2014). The extinction and large decline of breeding pairs recorded in Boussedra are explained by the fact that breeding is related to several environmental factors like habitat loss and water level changes (Battisti et al. 2006; Desgranges et al. 2006), in addition to human disturbances (Carney and Sydeman 1999; Onmuş and Siki 2013).

Thus, as shown by Boussedra Pond, small and isolated wetlands have an important ecological role in maintaining biodiversity by providing valuable habitat for waterbirds (Semlitsch and Bodie 1998; Scheffer et al. 2006; McKinney et al. 2011), especially for generalist and area-independent species (Paracuellos 2006; Ma et al. 2010; Smith and Chow-Fraser 2010), which are more tolerant to human disturbances, wetland size and urban areas. The results suggest that small wetlands may exhibit some form of resilience when subjected to limited habitat loss and fragmentation but this resilience may break down when habitat loss reaches a threshold. The extent to which a wetland can buffer against extreme changes such as drastic reduction of size may depend on the wetland's initial size and the scale of the change. However, further investigations on this topic are needed as perceptual traps can be misleading (Patten and Kelly 2010).

In terms of management priorities, small isolated wetlands thus deserve to have the same conservation attention that larger and less isolated wetlands receive (Malavasi et al. 2009) as the consequences of their cumulative loss may adversely impinge on key metapopulation processes (Bascompte and Solé 1996; Hanski 1999). However, their conservation in urban landscapes, requires a coordinated approach aimed at effective management measures that take into account the attitude and the active participation of stakeholders, in order to integrate environmental conservation and social context (Caughley 1994; Hage et al. 2010).

Declarations

Declarations

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethics approval

All procedures followed by this study were in accordance with international ethical standards and national legislation.

Consent to participate

Not applicable

Consent for publication

All the authors are in agreement with the version submitted and are in agreement with its publication in WETLANDS.

Availability of data and material

Data are *available* from the authors upon reasonable *request*

Code availability

Code is *available* from the authors upon reasonable *request*

Authors' contribution

A A, Collected field data,

F S, contributed in data analysis and in drafting the first version of the manuscript.

LT, contributed in data analysis,

RN, contributed in data analysis,

LS, Revised the manuscript,

BS, contributed in data analysis and in drafting the first version of the manuscript

All the authors, Revised the manuscript.

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Figures

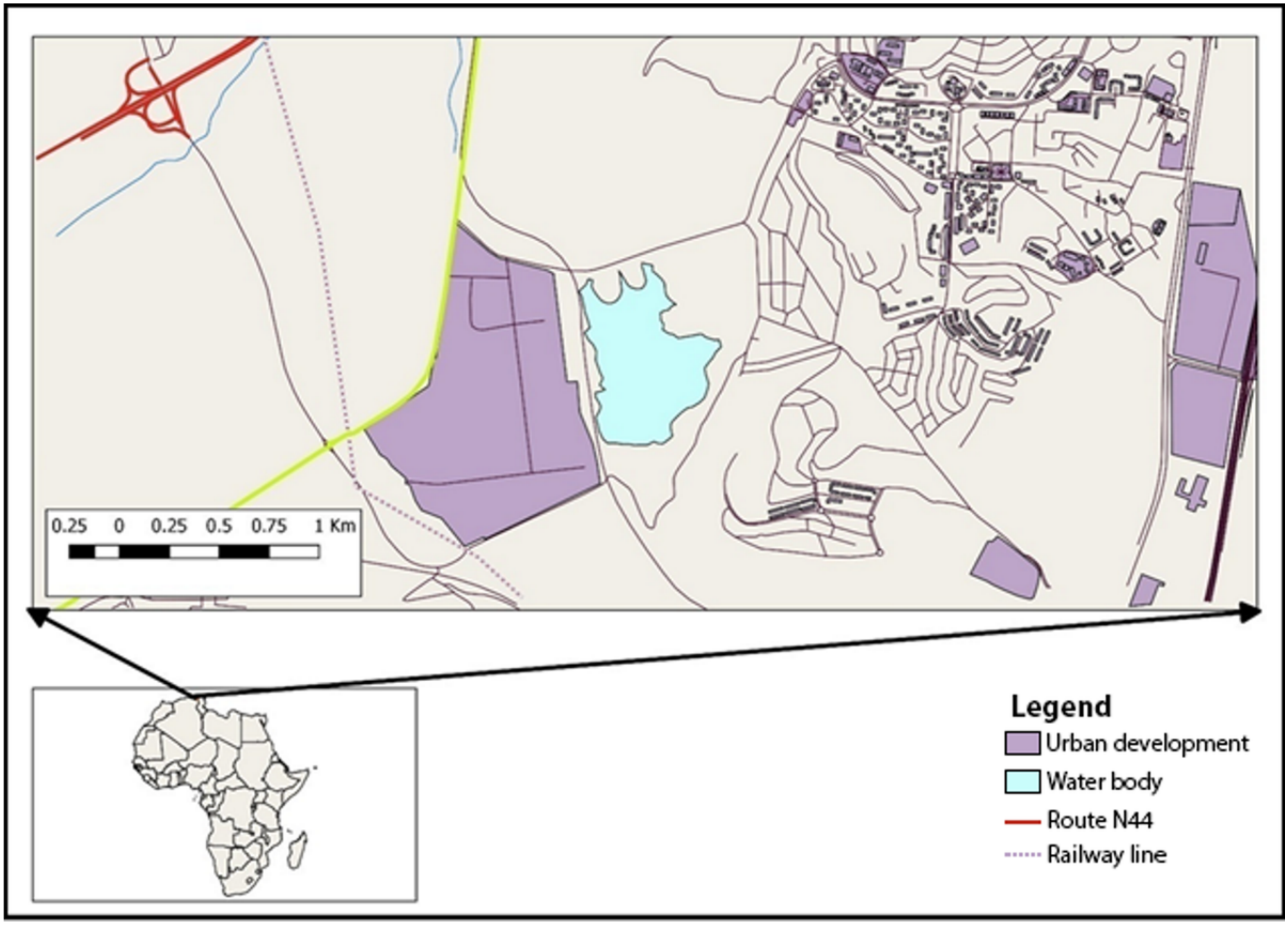

Figure 1

Location map of Boussedra Pond, north-eastern Algeria Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Boussedra Pond in October 2013: a) view of the northern shore; b) overview from the western side.

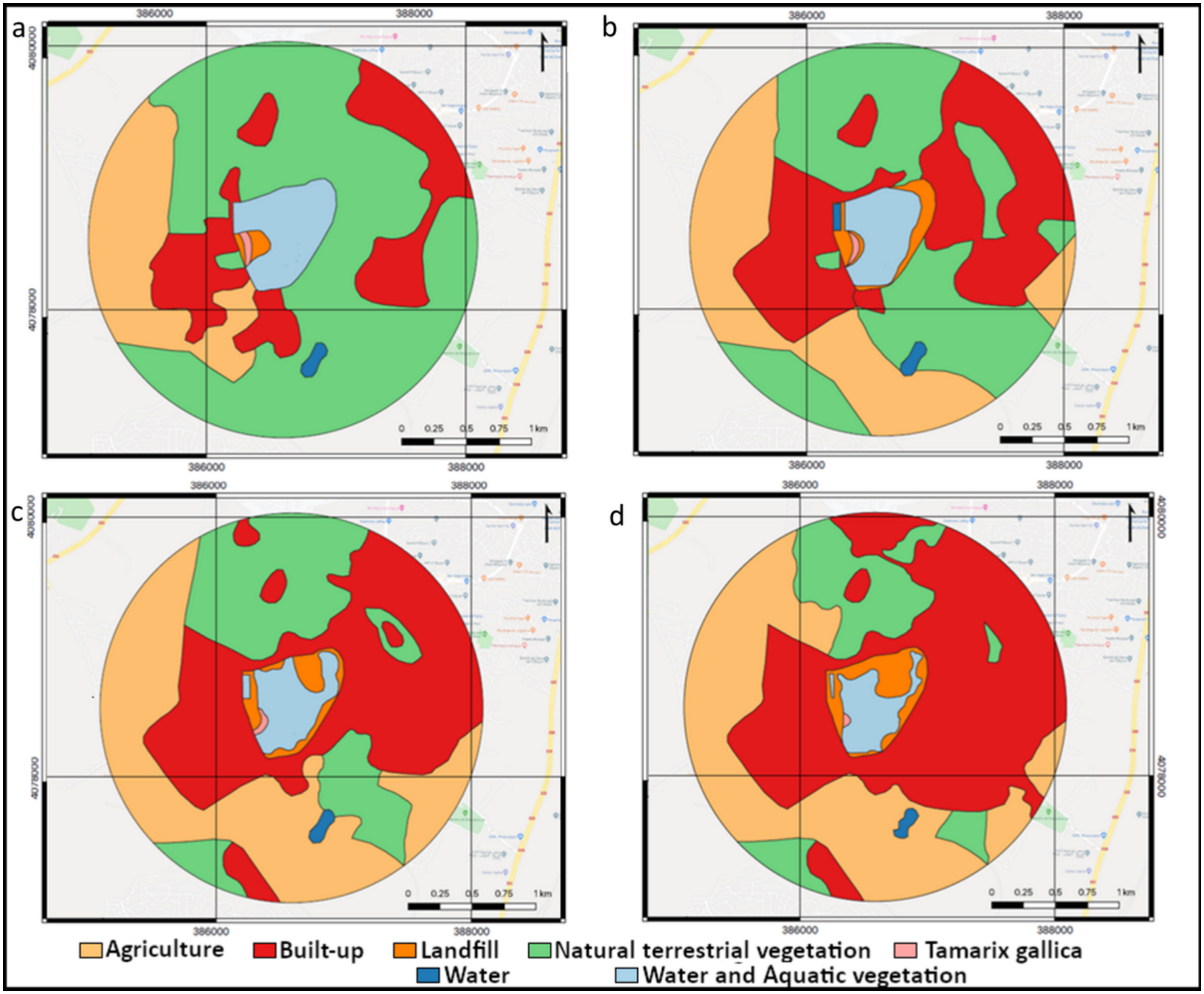

Figure 3

Changes in landscape cover in a 1 km buffer zone around Boussedra Pond between 1984 and 2018 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

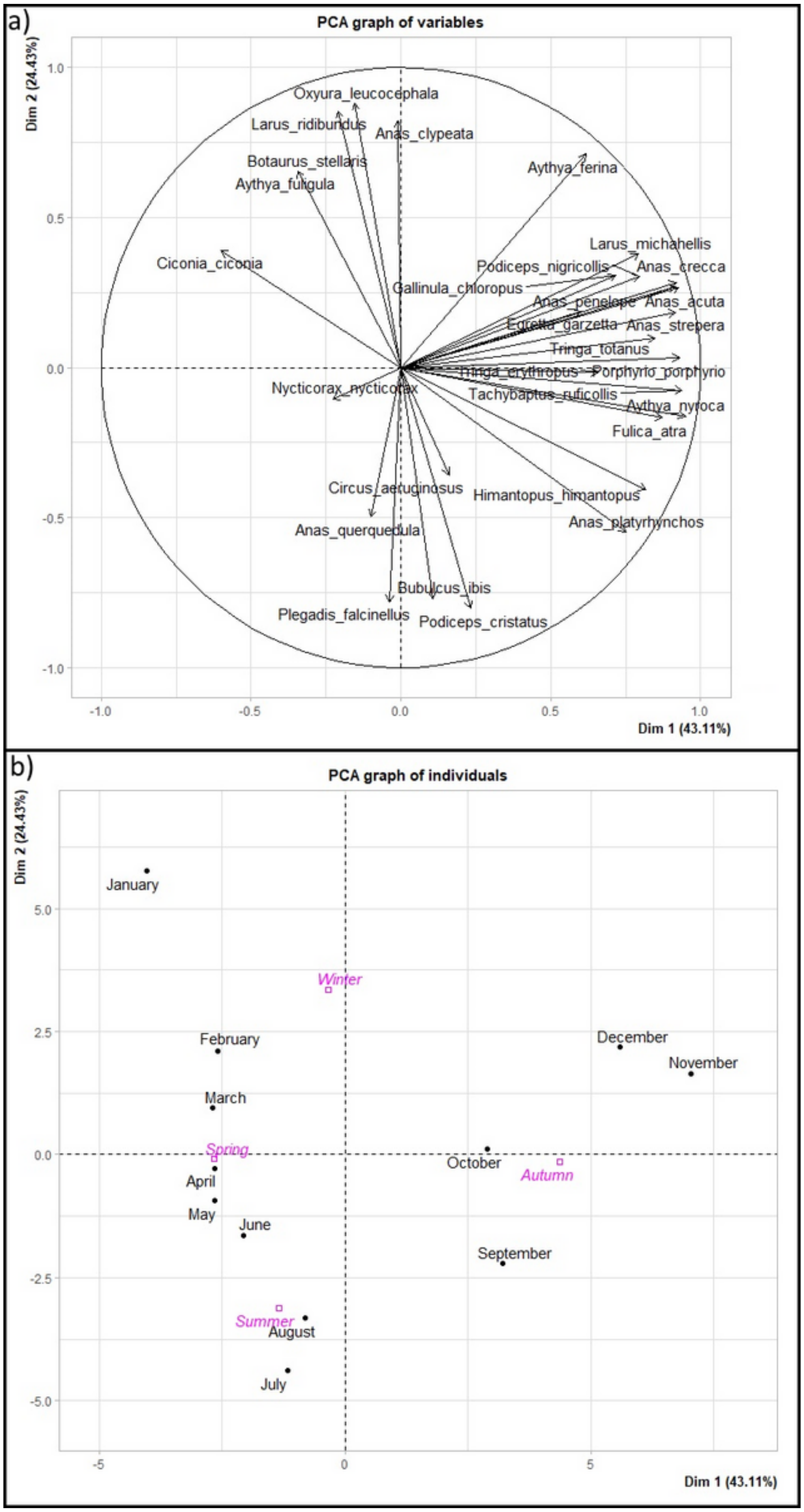

Figure 4

Principal component analysis (PCA) ordination based on species abundance data illustrating the seasonal patterns of the waterbird assemblages of Boussedra Pond