


Research Article

Status and Trends of the Ferruginous Duck's (*Aythya nyroca*) Wintering Population in Morocco: Analysis of 35 Years of Winter Census Data (1983-2017)

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The Ferruginous duck is a winter visitor and breeding resident in Morocco. The species breeds regularly in several coastal and inland wetlands, with remarkable numbers in some marshlands (*Sidi Boughaba*, *Fouwarate*, *Bargha*, *Bas Loukkos*, etc.). This duck is listed as near threatened in the IUCN Red List, and its populations have been in decline in many European countries. In Morocco, the national wintering population has known, during the last decade, a strong increase, in both its numbers (from tens to thousands of individuals) and distribution area (from a couple of sites to more than 21 wetlands). The *North-West* region of Morocco has been hosting regularly, during the last decade, between 31 and 91% of the Moroccan wintering population, which is mainly concentrated in two marshlands: *Merja de Fouwarate* and *Merja de Sidi Boughaba*. A small reservoir, *Barrage Hassar*, recently created in the *Centre-Atlantic* region, has also been, in recent years, one of the most important wintering sites of the species. 15 wetlands have hosted, at least once during the last decade, more than 1% of the regional population of “West Mediterranean/North and West Africa”. This work is an important step to a better knowledge of the Ferruginous duck's population. This knowledge is the basis for adopting adequate measures for the conservation of the species at the national and international level.

1. Introduction

The Ferruginous Duck *Aythya nyroca* (Güldenstädt, 1770) is a winter visitor and a breeding resident in Morocco [1, 2]; it winters regularly in the Northern part of the country, usually in small numbers, in comparison with Tropical Africa [2].

Recent breeding data show that the species breeds regularly in *Marais du bas Loukkos* [3], *Marais de l'wad Smir* [4], *Marais de Wad El Maleh* [5], *Merja de Sidi Boughaba* [6], and *Merja de Wad Fouwarate* [7]. In addition, unpublished data have been collected also from *Barrage El Mehraz*, near Fès city, and from a small marshland in Walidia. Nesting signs could be observed from late March till July, with a peak in egg lying in May and June [7, 8].

In Europe, the Ferruginous duck prefers shallow freshwater wetlands [9], generally rich in emergent vegetation [10–12], but it can occupy coastal ecosystems [13]. In Morocco,

this species is most commonly found in marshes and lakes with emergent plants (mainly *Typha*, *Phragmites*, *Scirpus*, *Sparganium*, *Cladium*, and *Carex*) that create safe nesting areas for the species [14].

According to recent data [15], the Ferruginous duck's global population is estimated at 180.700-238.000 individuals. The “West Mediterranean/North & West Africa” region, to which the Moroccan population belongs, holds 5.700-6.300 individuals. The species is indeed classified as “near threatened”, both in the IUCN Red List and on the CMS/AEWA Appendices (1, A-1a, and 1c), knowing that its global population is still declining [13]. This decline is mainly linked to habitat loss, particularly due to the destruction of freshwater bodies with dense vegetation [10, 11, 16]. An international action plan has been developed, aiming to conserve the species [17].

In Morocco, the Ferruginous duck, previously represented by very few individuals permitting to classify it as endangered, became recently more common, but still in a vulnerable situation, knowing that its habitats are relatively fragile.

This study presents an analysis of the winter census data of the Ferruginous duck during the 1983-2017 period in Morocco. This census was made in the context of the International Waterbird Census (IWC), conducted in Morocco regularly since 1983, in close coordination between the Scientific Institute (Study Centre of Bird Migration), GREPOM (Research Group for Bird Protection in Morocco), and the Medwaterbirds Network [18]. We will focus in this work on spatiotemporal patterns of the species and its best wintering sites.

2. Materials and Methods

This study is based on the data collated from the national information system used to manage the *International Waterbird Census* in Morocco. These data are compiled in annual tables with a simple format (sites x species) that could be used to calculate average numbers and trends in time.

To determine the national population size, only recent data (2008-2017) are used. This parameter is estimated by the national average of the total wintering numbers, which is obtained by summing the average of the annual numbers in each site. This estimation is more precise than the average of the annual total of numbers counted in the country. These same data are used to illustrate the winter distribution of the species, using ArcMap tools.

The analysis of the specific data to each site permitted to identify wetlands verifying the 6th Ramsar criterion, considering that a site verifies this criterion for the Ferruginous duck, when this species reaches the 1% of its regional population, at least once during the last decade.

The trend pattern of the national wintering population was analyzed for the 35 years (1983-2017), during which the IWC was regularly conducted. This analysis was undertaken using TRIM (TRends and Indices for Monitoring Data), a freeware program, developed by Statistics Netherlands in the framework of wildlife statistics. This program analyzes time series of counts, using log linear Poisson regression, and produces estimates of yearly indices and trends. This tool deals with several difficulties inherent to monitoring data, especially missing values and undersampling of certain sites compared to others [19]. In Morocco, many sites were not regularly visited, mainly before 1991, either due to difficult access (e.g., heavy snowfall) or simply due to a lack in logistical capacity.

The results of the trend analyses are translated into six possible trends categories: (1) **strong increase** (significantly more than 5% per year), (2) **moderate increase** (not significantly more than 5%), (3) **stable** (no significant increase or decline, and it is certain that trends are less than 5% per year), (4) **uncertain** (no significant increase or decline, but not certain if trends are less than 5% per year), (5) **moderate decline** (not significantly more than 5% per year), and (6)

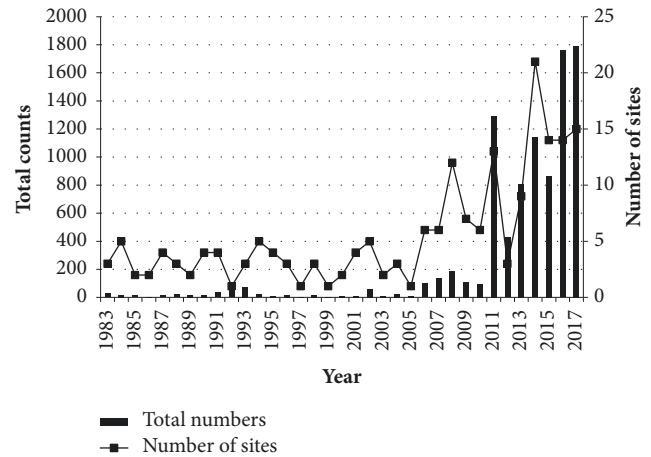


FIGURE 1: Evolution of the total winter counts and the number of wetlands where the Ferruginous duck has been observed in Morocco during the period 1983-2017.

steep decline (significantly more than 5% per year, meaning a halving in abundance within 15 years).

3. Results

3.1. Population Size. The 35-year counts (See Table S1 in the Supplementary Material for the counts raw dataset) show an increase of the national population size, as well as the number of wintering sites of the Ferruginous duck (Figure 1). Until 2008, this number varied from year to year, between 2 and 6, while the total number of wintering sites was limited to 12 wetlands. This number increased progressively and reached its maximum level (21 wintering sites) in 2014. The wintering numbers increased particularly during the 2011-2017 period, where annual totals varied between 400 and 1,800, the lowest number being in 2012 (about 400 ducks), due to an undersampling of sites, and the maximums in 2016 and 2017.

This increase in the number of the species wintering sites could be correlated to the increase in the number of sites visited, which translates an improvement in the census effort. However, this effort does not correlate with the remarkable evolution of the wintering population (from a couple to thousands of individuals). This is well illustrated by the case of the 2014 census, where visited sites reached their highest number (115 wetlands), but the wintering Ferruginous ducks were not at their highest numbers and their distribution did not exceed 18% of the total visited sites.

3.2. Population Trend. The trend pattern of the wintering population was analyzed by the TRIM software over the last 35 years (1983-2017). This model was applied to all the sites where wintering Ferruginous ducks were recorded. The total number of counts is 1,820, and 953 counts were missing. In fact, several sites are irregularly visited, some of them being visited only once during the last 35 years. Moreover, some wetlands (mainly dams) have only been recently included in the national network of the winter census program.

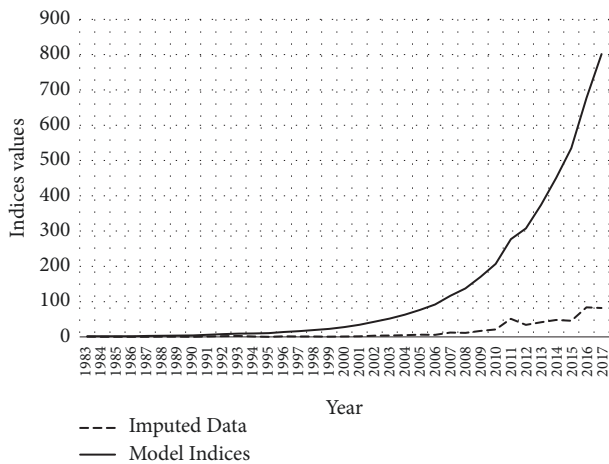


FIGURE 2: Linear trend of the Ferruginous duck's wintering population (TRIM analysis).

The result of this analysis has shown a recent strong increase of the wintering population of the species (Figure 2). However, more than 10% of the wintering individuals were hosted by two sites: *Merja de Wad Fouwarate* and *Merja de Sidi Boughaba*, located near Kenitra city (North-West of Morocco).

3.3. Winter Distribution. During the first IWC (International Waterbirds Census) organized in Morocco (on 1983), the Ferruginous duck was reported from three sites in distinct regions, with less than 20 individuals each: *Barrage Mechra' Hommadi* in the North-East, *Dayet 'Awa* in the Middle Atlas, and *Embouchure de l'wad Massa* in the South-West. Then, the wintering population showed, throughout the years, a progressive expansion to other sites, reaching 52 wetlands in 2017.

However, wintering Ferruginous ducks are generally concentrated in the Northern part of Morocco, especially the *North-West* region, which hosted, during the last ten years, between 31 and 91% of the national population (Figure 3). The *Centre-Atlantic* and the *North-East* region come in second rank, since they have hosted up to 39% of the wintering individuals, followed by the *Atlas* and *South* region, which hold around 15% of the national population and exceptionally, 49% for the *Atlas* region in 2008 (thanks to *Dayet 'Awa*), and 64% for the *South* region in 2010 (thanks to *Barrage Zelmou*).

Highest concentrations are observed in marshlands on the Atlantic and Mediterranean littorals (Figure 4), but also in some inland lakes and dams (in *Middle Atlas*, *Saïss* plain, *Centre-Atlantic*, and *North-East*). Substantial numbers could be counted in some river mouths and lagoons.

Five wetlands have hosted 78% of the national wintering population during the last decade (Table 1): *Merja de Wad Fouwarate*, *Merja de Sidi Boughaba*, *Barrage Hassar*, *Barrage Mohamed V*, and *Dayet 'Awa*.

Three dams are visited by significant numbers of wintering individuals but with less regularity:

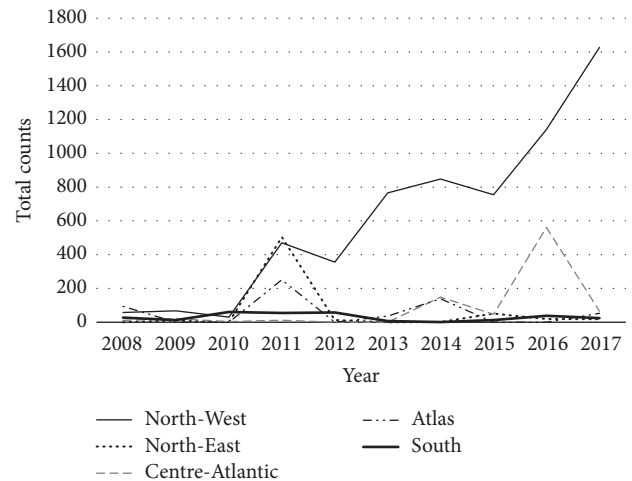


FIGURE 3: Evolution of the Ferruginous duck's total numbers by region during the last decade.

- (i) *Barrage Mohammed V*, where the first occurrence of the Ferruginous duck has been reported in 2007, with a maximum of 400 individuals observed in 2011
- (ii) *Barrage Al Wahda*, where census started only recently, cumulating three visits (2014 to 2016), and which could be a potentially important wintering site for the species, since 99 wintering individuals have been observed in 2016
- (iii) *Barrage Hassar*, in the *Centre-Atlantic* region, which has been visited for the first time in 2014 and could host more than 500 wintering individuals

Based on recent data, the most regular wintering sites in Morocco, where the Ferruginous duck has been reported at least 80% of the time (Table 1), are *Merja de Sidi Boughaba*, *Barrage Zelmou*, *Merja de Wad Fouwarate*, *Dayet 'Awa*, and *Marais du bas Loukkos*.

The presence of the species in other sites can be irregular (such as the case for *Embouchure de l'wad Massa*, *Merja Bargha*, etc.), rare, or exceptional/accidental (e.g., *Baie d'Ad-Dakhla*, where only one individual has been observed in 1995).

3.4. Sites Verifying the 6th Ramsar Criterion. To apply the 6th Ramsar criterion to the Ferruginous duck's wintering data, the threshold used is 25 birds, corresponding to 1% of the regional population of "West Mediterranean/North & West Africa" [15].

During the last ten years (2008-2017), this threshold has been exceeded at least once in 15 wetlands (Table 2). *Merja de Wad Fouwarate* and *Merja de Sidi Boughaba*, in the *North-West* region, come first by verifying this criterion, respectively, seven and six winters. Another lake, *Dayet 'Awa*, in the *Middle Atlas*, reached this threshold three times. Three artificial reservoirs also verify this criterion 3-4 times; two of them, *Barrage Zelmou* and *Barrage Mohammed V*, are in the *North-East* of Morocco and the third, *Barrage Hassar*, is in the *North-West* region. The remaining wetlands have verified this criterion only 1-2 winters during the last 10 winter counts.

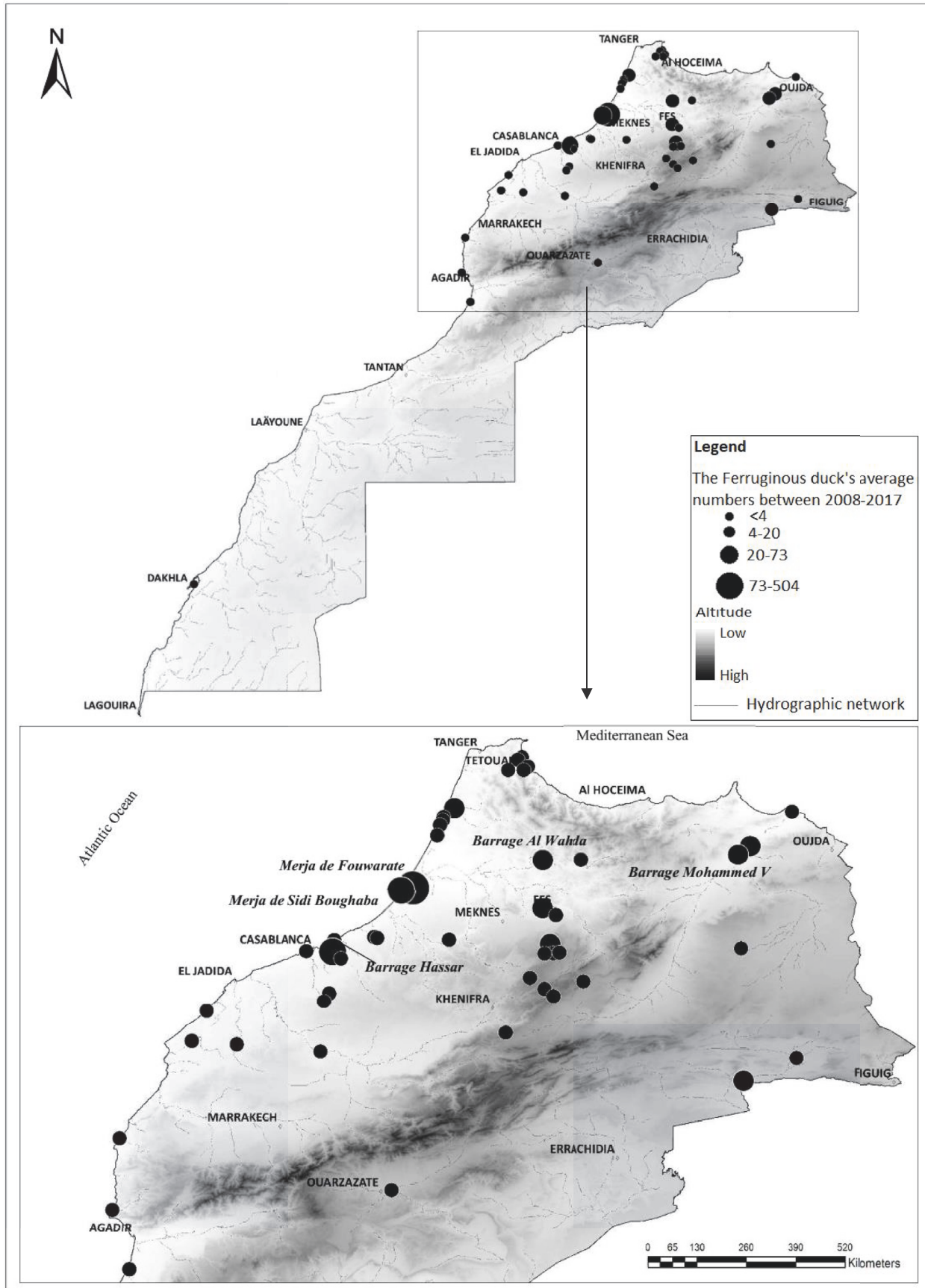


FIGURE 4: Distribution map of the Ferruginous duck's wintering population in Morocco.

TABLE 1: Most important wintering sites of the Ferruginous duck.

Site name	Average 2008-2017	Maximum	Occurrence	Number of censuses	1 st census
Merja de l'wad Fouwarate	504	1200	8	19	1990
Merja de Sidi Bou Ghaba	221	400	21	32	1983
Barrage Hassar	174	516	4	4	2014
Barrage Mohammed V	73	400	4	24	1984
Dayet 'Awa	53	195	8	29	1983
Barrage Al Wahda	33	99	1	3	2014
Barrage Zelmou	26	58	9	10	2007
Barrage Mechra' Hommadi	25	76	3	13	1983
Plan d'eau de Dwiya	22	22	5	15	1983
Marais du bas Loukkos	21	68	20	34	1984
Aguelmam Afennourir	19	56	3	26	1983
Merja Bargha	16	63	9	26	1988
Aguelmam N'Tifounassine	14	30	2	21	1987
Réserve royale Ain Sferjla	11	15	2	2	2009
Barrage Al Himer	10	10	1	1	2014
Dayet Ifrah	9	33	3	29	1983
Dayet Hachlaf	9	24	3	7	1997
Daya Bennejma	9	17	1	2	2016
Lagunes de Sidi Moussa-Walidia	7	44	5	33	1983
Marais de Wad Al Maleh	7	12	4	6	2001

TABLE 2: Wetlands hosting, at least once, more than 1% of the Ferruginous duck's regional population.

Site name \ Years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	1% RP*
Merja de l'wad Fouwarate				324	356	680	450	386	634	1200	7
Merja de Sidi Bou Ghaba	22			83		72	250	320	400	400	6
Barrage Zelmou	9	5	57	52	58	7		5	20	25	4
Barrage Mohammed V		5		400				35			2
Barrage Hassar							124	45	516	12	3
Dayet 'Awa	65			195		2	46			7	3
Marais du bas Loukkos	14	68	13			5	61	24	6	19	2
Merja Bargha				50		8	63	9			2
Barrage Al Wahda									99		2
Aguelmam N'Tifounassine						30	27				2
Barrage Mechra' Hommadi				76							1
Lagunes de Sidi Moussa-Walidia								2	10	44	1
Côte et Archipel d'Essawira									35	4	1
Dayet Ifrah							33			22	1
Aguelmam Afennourir	21			56			16				1
No. of sites verifying the 1% threshold	1	1	1	8	2	3	8	4	5	4	

*Number of times the 1% of the Regional Population of the species ("West Mediterranean/North & West Africa") (25 individuals) has been reached or exceeded.

Some Ferruginous ducks winter in several wetlands that already have national or international conservation status (Table 3). Thereby, 15 wetlands are Important Bird and Biodiversity Areas (IBAs), while 14 are Ramsar sites

and two others are candidates to this status. Moreover, 25 wetlands have a national conservation status known as SIBE (Sites of Biological and Ecologic Interest). Among the 28 wetlands of national and/or international importance, 9 of

TABLE 3: Conservation statuses of the Ferruginous duck's wintering sites.

Site name	Types of habitat	Region	Ramsar status	SIBE ¹	IBA ²
Marais de l'wad Smir	Marshland	North-West	Candidate	X	
Barrage de Smir	Artificial reservoir / Dam	North-West	Candidate		
Marais du bas Loukkos	Marshland	North-West	X	X	X
Merja des Wlad Skher	Marshland	North-West		X	
Merja Bargha	Marshland	North-West		X	X
Merja Al Halloufa	Marshland	North-West		X	X
Merja Zerga	Marshland	North-West	X	X	X
Merja de l'wad Fouwarate	Marshland	North-West	X	X	
Merja de Sidi Bou Ghaba	Marshland	North-West	X	X	X
Plan d'eau de Dwiya	Lake	North-West			X
Embouchure de l'wad Malwiya	River mouth	North-East	X	X	X
Barrage Mohammed V	Artificial reservoir / Dam	North-East	X	X	X
Marais de Wad Al Maleh	Marshland	Centre-Atlantic	X		
Barrage de l'wad Al Mellah*	Artificial reservoir / Dam	Centre-Atlantic		X	
Lagunes de Sidi Moussa-Walidia	Lagoon/Marshland	Centre-Atlantic	X	X	
Barrage Al Massira	Artificial reservoir / Dam	Centre-Atlantic	X	X	X
Côte et Archipel d'Essawira	Coastal wetland	Centre-Atlantic	X	X	X
Dayet 'Awa	Inland lake	Atlas		X	
Dayet Ifrah	Inland lake	Atlas		X	
Plan d'eau de Zerrouqa	Inland lake	Atlas		X	
Aguelmam Afennourir	Inland lake	Atlas	X	X	X
Aguelmam N'Tifounassine	Inland lake	Atlas	X	X	
Aguelmams Sidi Ali-Ta'nzoult	Inland lake	Atlas		X	X
Aguelmam Abekhane	Inland lake	Atlas		X	
Barrage Al Mansour Ad-Dahbi	Artificial reservoir / Dam	South		X	X
Embouchure de l'wad Tamri*	River mouth	South		X	X
Embouchure de l'wad Massa	River mouth	South	X	X	
Baie d'Ad-Dakhla*	Bay	South	X	X	X

¹ Sites of Biological and Ecological Importance.

² Important Birds and Biodiversity Areas.

* The Ferruginous duck has been reported only once in those wetlands (1-2 ducks).

them benefit from all three national and international conservation statuses and 10 are protected by at least two conservation statuses.

4. Discussion

The main purpose of this paper was to provide current and historical statuses of the wintering population of the Ferruginous duck in Morocco. The available data of winter census, from 1983 to 2017, has shown a strong increase in numbers of both wintering birds and sites.

However, the precise global trend of the species remains unknown [13], but the general profile of the population shows local decline, especially in Europe. Data on Asian populations suggest evidence of decline but is sometimes contradictory [13]. Therefore, the overall population is considered as declining at moderate rates as a precautionary measure, and the species is still classified as "near threatened" in the IUCN Red List [13].

The Moroccan population of the Ferruginous duck shows an increase in its wintering and breeding individuals. Our

data is consistent with the most recent trend analyses of the Ferruginous duck's population, specifically in the "West Mediterranean/North & West Africa" region. In fact, after a strong decline at both international and regional levels, the regional population of this species has grown to reach the recent estimate of 5,700-6,300 individuals [15]. Although North Africa represents an important stopover for the species, it generally hosts small numbers, compared to East Africa (e.g., Sudan, Ethiopia), which is the main wintering area for this duck [20]. Nevertheless, the species has been expanding to Tunisia [21, 22], where up to 80 pairs have been reported in a dozen wetlands [21, 23] and increasing numbers have been recorded during the wintering period [24]. Furthermore, Algerian wetlands are the most important breeding and wintering sites for the species in North Africa. They host its highest concentrations [8, 21, 25-30], especially in the Northeast region, where wintering numbers fluctuate between 1500 and 3500 individuals [26] and more than 700 pairs breed at Lake Tonga alone [21]. Overall, the species population in Algeria seems to be improving [25, 30, 31], even though it is not the case in some Algerian wetlands [32],

where anthropogenic pressures are negatively impacting its population [29, 33].

The Ferruginous duck faces indeed many threats that are mainly related to the destruction of wetlands habitats, especially the ones with dense vegetation [10, 11, 16, 17], and changes in water regimen and levels. Other factors contributing to the decline in the global species populations are related to the introduction of nonnative species and predators [17]. The increased drought due to climate change can also pose a threat [16, 17, 34], as its breeding depends on sufficient water levels, which can play a role in maintaining feeding areas for ducks and potentially decreasing the predation rate of nests [8, 14, 29, 35]. Moreover, hunting represents a serious threat to the species, especially during the autumn passage and on its wintering areas in East Africa (e.g., Sudan) [11, 36]. Additionally, significant numbers are illegally killed each year, especially in Serbia, Libya, and Croatia [37].

All these threats faced by the Ferruginous duck make it vulnerable and contribute to the general decline of its population. This could potentially point out to a possible decline or possible shift in its European breeding populations.

Multiple hypotheses could explain the increase in wintering populations in Morocco.

One hypothesis could be related to the hosting capacity of national wetlands and the moderate meteorological conditions in Morocco, offering the species shelter and good feeding grounds. In fact, contrary to the IPCC (Intergovernmental Panel on Climate Change) models predicting lower rainfall and increased aridity, there is a gradual return to wetter conditions in Morocco since 2008 [38], contributing to good water levels. Indeed, the Ferruginous duck tends to occupy new areas if their climatic conditions become more wet, as it was the case for China [39].

Although the available data on the trend of breeding populations shows conflicting and fluctuating trends, according to Robinson and Hughes [17], with up to 37% of the countries where the Ferruginous duck breeds, having no estimate of population trend; another hypothesis could be related to successful conservation measures established in Europe (e.g., habitat management in Bulgaria and reintroduction schemes in Italy [40]), contributing to a possible increase in the breeding success of the species, thus in the numbers of wintering individuals.

A third hypothesis for the Ferruginous duck's Moroccan population increasing trend is the shifting of a part of its regional population to Morocco, either from the wintering population in East Africa or a part of the breeding population in Europe which became resident in the country, because of a more suitable environment.

As stated by Robinson and Hughes [17], in the International Action Plan for the Conservation of the Ferruginous duck, many data gaps on the species population remain, which could be crucial to having a better knowledge and understanding of the populations estimates and trends and thus be able to adopt and implement the right conservation measures to restore the species populations to a stable level.

4.1. Key Wintering Sites in Morocco. The distribution of the Ferruginous duck over the national territory and the sites it occupies is consistent with its preferred habitat (mainly freshwater habitats with dense vegetation).

It is mostly concentrated in the *North-West* region of Morocco, on the Atlantic coast. Two wetlands have hosted regularly and most frequently the highest numbers of wintering individuals: *Merja de Wad Fouwarate* and *Merja de Sidi Boughaba*. The latter is a Ramsar site since 1980 and the first one has just been classified in 2018.

Other sites have hosted high numbers of the Ferruginous duck. But for some of them, the census effort is either recent (e.g., the first census for *Barrage Hassar* was in 2014) or not regular. Nevertheless, we consider that the wetlands that have been hosting high numbers of the Ferruginous duck's wintering individuals (more than 1% of its regional population) and for at least 7 winters are of national importance for the species.

Identifying the key wintering sites of this threatened duck is crucial to call for appropriate conservation measures for these wetlands. In fact, even though our country has been hosting increasing numbers of the Ferruginous duck, the future of its growing population depends on the conservation of its privileged sites, which face growing threats related, especially, to habitat loss [41].

5. Conclusion

This study has given an overview on the recent status and population trend of the Ferruginous duck in Morocco. The species used to winter in the country, as in the rest of the Maghreb region countries, in small numbers. Nonetheless, the species has known a strong increase in its population, at the national level, over the years, as much as in its distribution, since it is also breeding in new sites.

The results obtained indicate that the three major wintering sites of the species are *Merja de Wad Fouwarate*, *Merja de Sidi Boughaba*, and *Barrage Hassar*. The species also winters more or less regularly in other wetlands that often host more than 1% of its regional population (15 sites in the last ten years).

This work is but a first step into a better knowledge on the Ferruginous duck's population at the national level. Future work should research the factors influencing the distribution of the species and its choice of wintering and potentially suitable breeding sites.

Concerted efforts should also be conducted to acquire more data on the species at the regional and global level, since a lot of information on the estimates and trends of its global population remains unknown or uncertain.

Data Availability

All data generated or analyzed during this study are included in this published article (and its supplementary material files).

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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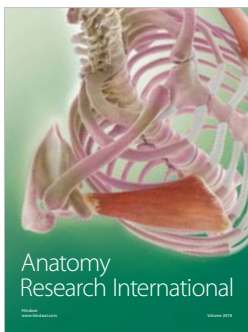
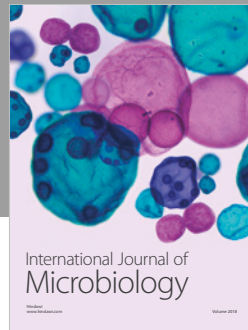
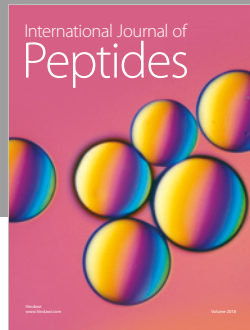
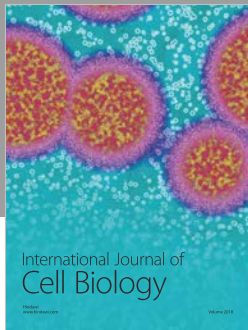
Supplementary Materials

Table S1: national counts of the Ferruginous duck's wintering individuals per year and per site. (*Supplementary Materials*)

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