

Research Article

Distribution and Numbers of Three Globally Threatened Waterbird Species Wintering in Morocco: The Common Pochard, Marbled Teal, and White-Headed Duck

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Morocco plays a key role in the life of many migratory birds and their survival, thanks to the diversity and richness of its ecosystems. The International Waterbird Census (IWC) has been regularly implemented in Morocco since 1983. Thanks to this program, a large database on wintering waterbirds' populations has been collected. In this article, we summarize the wintering data of three globally threatened waterbirds: *Aythya ferina*, *Marmaronetta angustirostris*, and *Oxyura leucocephala*. The population of *Aythya ferina*, which is declining, is largely distributed in the country, in over a hundred wetlands, 26 of which verify the national importance criteria. *Marmaronetta angustirostris* has a stable trend over the years even though its population can know high annual fluctuations; it winters in more or less 50 wetlands, among which 18 host more than 1% of its regional population and 16 verify the criteria for national importance. On the contrary, *Oxyura leucocephala*, a globally endangered bird only encountered in a dozen wetlands, shows a moderate increase in its numbers; only two wetlands verify the Ramsar criterion 6, while a total of six can be considered of national importance. Furthermore, given the conservation statuses of these waterbirds and according to the Ramsar criterion 2, all their hosting sites are of international importance. The results presented in this paper are a crucial step for the adoption and implementation of adequate conservation measures for the species and their key sites. Nevertheless, comprehensive research and coordinated efforts on the factors (ecological and anthropogenic) influencing the species, at the national and international levels, are required for a better understanding of their populations' dynamics.

1. Introduction

Morocco is a North African country, with highly diversified ecosystems and coastlines along both Atlantic Ocean and Mediterranean Sea [1, 2]. It is located at the crossroads of many bird migration routes between Europe and Tropical Africa, and its wetlands play a crucial role for thousands of birds as stopover, wintering, and breeding areas [3, 4]. The country has ratified almost all international and regional agreements for the conservation of these birds and their habitats. In the context of the Ramsar Convention and the African-Eurasian Migratory

Waterbird Agreement, the country undertakes regular waterbird censuses that provide an appropriate basis for effective decision-making in their conservation. In fact, Morocco has been regularly participating, since 1983, in the International Waterbird Census (IWC), one of the largest biodiversity monitoring programs in the world, thanks to the coordination of the Study Centre of Bird Migration (in the Scientific Institute) and the collaboration of GREPOM/BirdLife Morocco, which provides the majority of field volunteers.

This article provides new syntheses on three globally threatened species of Anseriformes [5]: the White-headed

Duck *Oxyura leucocephala* (Scopoli, 1769), an endangered bird [6], and two vulnerable species the Marbled Teal *Marmaronetta angustirostris* (Ménétriés, 1832) [7] and the Common Pochard *Aythya ferina* (Linnaeus, 1758) [8].

The Common Pochard is a Eurasian duck found in a wide variety of wetlands (marshes, lagoons, lakes, artificial reservoirs, and rivers), with eutrophic to pH neutral waters, but it mostly prefers large open bodies of water with abundant emergent vegetation [8–10]. In Morocco, it is a winter visitor, passage migrant, and occasional to regular breeder [4, 11, 12]. Evident nesting cases have been observed in five Northern marshlands: “Plan d’eau de Dwiya” [4, 13], “Merja Bargha” [4, 14], “Marais de Smir” [15], “Merja de Sidi Bou Ghaba” (with the highest number of breeding pairs, nationally: 25 in 2011) [16], “Merja de Fouwarate” [17], and in two Atlas lakes (“Aguelmam Afennourir” and “Dayet ‘Awa” [4]). The threats faced by the species and its limited breeding population have rendered it vulnerable in Morocco [16].

The Marbled Teal is commonly found in shallow brackish wetlands [18], with rich emergent and submerging vegetation [9, 19, 20], avoiding open-water areas [20–22]. However, its distribution largely varies with seasons, especially depending on its dietary needs [18]. In Morocco, it is a resident breeder, winter visitor, and passage migrant [4, 11]. Its breeding population was estimated to 50–250 pairs [23], distributed in a dozen wetlands situated in the north and south of the country [4, 16, 17, 23–25]. Nevertheless, It regularly breeds in four wetlands [16, 17, 24]: “Merja de Sidi Bou Ghaba,” “Merja de Fouwarate,” “Plan d’eau de Dwiya,” and “Embouchure de Wad Massa.” The species is considered endangered in Morocco [16] mainly because of its habitat degradation and modification [16].

The White-headed Duck is the only Palearctic species of the *Oxyurini* tribe [26]. Breeding birds are usually found in freshwater and brackish or eutrophic lakes with dense emergent vegetation [22, 27], shallow and permanent or semipermanent [9], while wintering birds can be found in deeper and larger wetlands, alkaline or saline, and with less vegetation [28]. In Morocco, it is a winter visitor, resident breeder, and suspected passage migrant [11]. It used to breed in Morocco until the 20th century, before becoming scarce and disappearing, due its habitats’ loss by agricultural development and droughts [25]. Since the 1990s, the species reappeared in “Plan d’eau de Dwiya” [4, 29] and then expanded progressively to several other breeding sites [30, 31]: “Merja de Sidi Bou Ghaba,” “Merja de Fouwarate,” “Barrage ‘Arabat,” “Barrage El Mehraz,” “Merja Bargha,” cumulating about 60 couples. It is still vulnerable in Morocco [12].

2. Methodology

2.1. Counting Procedure. Our study is based on the dataset of the waterbirds’ winter census, between 1983 and 2019. The counting procedure was adopted according to standard bird monitoring techniques [32], and the protocol was refined over the years [14, 33–35]. The censuses are conducted annually, usually during January, to avoid recounts.

Nevertheless, given the large number of wetlands to be censused, some missions can start in late December (especially in the Saharan region). Moreover, in some rare cases, data from censuses during the 1st week of February were accepted; they were conducted in some sites (Atlas lakes) that were not accessible, during January, because of heavy snow. The number of wetlands censused, at least once, in the context of this program is 272 (IWC wetlands network). However, not all of them are visited every year, depending on the availability of human, financial, and logistical resources. The priority is always given to the wetlands with the highest waterbirds’ numbers and specific richness.

During each visit, the observers (Table S4) counted all waterbirds on the grounds, in the water, and even those flying inside the site, using binoculars and telescopes. Counting points and transects are determined for each wetland, depending on its configuration and accessibility. When some wetlands are close to one another, in a way that allows frequent bird exchange between them, they are considered as complex sites and are covered during the same visit. Over the years (especially since the 1990s), most wetlands have been censused by the same group of observers, using the same protocol; this makes the obtained data more homogenous, comparable, and reliable. The observers participating in the IWC program are ornithologists, qualified and trained for bird identification. New observers can join the program after going through training sessions on bird identification and counting methods, both theoretical and practical. During their learning phase, they can join the established observers’ teams during their census campaigns to strengthen their training.

2.2. Data Analysis. The wintering waterbirds’ numbers are entered in an information system, which generates automatically tables per species and sites.

To calculate populations’ trends, we used the TRIM (TRends and Indices for Monitoring Data) freeware [36] (version 3.54). TRIM generates estimations for missing counts and can analyze data for 4000 sites, over 100 years; this makes it very suitable for our large dataset, especially since not all sites are visited every year (Table 1). The missing data imputations take into account a site effect and a time effect, assuming the counts in a year depend on those of the year before (serial correlation). The counts are assumed to be Poisson distributed and are converted into annual indices to simulate the missing data and calculate trends, based on the completed dataset (with the first year as base year, to which the index 1 is attributed). The overdispersion (when the variance is larger than expected for a Poisson distribution) and the serial correlation can be estimated by TRIM, through a generalized estimating equation (GEE) approach.

The recommended overall slope by TRIM is based on the imputed data and given with the results of the additive slope and the multiplicative slope, which reflects the magnitude of annual change, as well as their standard errors. It is converted into one of six trend categories: (i) strong increase: an increase significantly greater than 5% per year; (ii) moderate

TABLE 1: Number and percentage of wetlands visited per year.

Year	Number of surveyed wetlands	% of the IWC wetlands network (272)
Average	73	27
1983	47	17
1984	82	30
1985	49	18
1986	35	13
1987	69	25
1988	69	25
1989	56	21
1990	71	26
1991	94	35
1992	86	32
1993	94	35
1994	77	28
1995	89	33
1996	46	17
1997	70	26
1998	65	24
1999	65	24
2000	62	23
2001	65	24
2002	56	21
2003	62	23
2004	65	24
2005	59	22
2006	66	24
2007	77	28
2008	85	31
2009	79	29
2010	62	23
2011	100	37
2012	43	16
2013	78	29
2014	115	42
2015	70	26
2016	88	32
2017	76	28
2018	99	36
2019	131	48

increase: a significant increase, but not significantly more than 5% per year; (iii) stable: no significant increase or decline, and it is certain that trends are less than 5% per year; (iv) uncertain: no significant increase or decline, but not certain if trends are less than 5% per year; (v) moderate decline: significant decline, but not significantly more than 5% per year; (vi) steep decline: decline significantly greater than 5% per year. A significance threshold is also provided for the increasing and declining trends: (i) highly significant: $p < 0.01$ (i.e., confidence level of 99%); (ii) significant: $p < 0.05$ (i.e., confidence level of 95%).

For the Common Pochard and the Marbled Teal TRIM analyses, three periods were considered: long term (1983–2019), medium term (2000–2019), and short term (2010–2019). For the White-headed Duck, which has been regularly observed in Morocco only starting 2005, the trend was calculated for the periods of 2005–2019 (long term) and 2010–2019 (short term).

To better understand the species evolution, we used different parameters, mainly as follows:

- (i) The average number of a species in each site is calculated for the long term and short term and corresponds to the arithmetic mean.
- (ii) The national average corresponds to the sum of the average numbers in each site.
- (iii) The total annual numbers correspond to the sum of the species numbers in each site for every year.
- (iv) The total number per site is the sum of all the species numbers observed per year in said site.
- (v) The occurrence of a species in a site corresponds to the number of winters it has been observed in this site.
- (vi) The census number of a site corresponds to the number of years during which it has been visited.

- (vii) The occurrence percentage of a species in a site corresponds to the ratio of its occurrence to the site's census number.
- (viii) The 1st census of a site corresponds to the first year during which it has been visited.
- (ix) The standard deviation was calculated for each site, to determine the deviation of the numbers observed annually from the average.

$$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{N}}, \quad (1)$$

where x_i is the observed number in site i , \bar{x} is the arithmetic mean, and N is the number of observations.

To prioritize future conservation measures, we have identified for each species, categories of key sites, based on recent data (2010–2019):

- (i) Sites of international importance, priority 1 (SII1): wetlands verifying the 6th Ramsar criterion (the species' numbers reach or exceed regularly (5 winters or more) 1% of its regional population.
- (ii) Sites of international importance, priority 2 (SII2), verifying the 2nd Ramsar criterion (sites supporting vulnerable, endangered, or critically endangered species).
- (iii) Sites of national importance (SNI): the species' average number, in those sites, equals or exceeds the 1% of the national average.
- (iv) Sites of potential national importance (SPNI): they hosted, during at least winter, more than 1% of the national average.

3. Results

3.1. Populations' Size and Trend. The national average of the Common Pochard's wintering population is 11.158 in the long term, the total annual numbers varying between 1.710 (in 2012) and 20.458 ducks (in 2002) (Figure 1). During the last decade (2010–2019), the national average is lower (7.496 individuals), but it represents 1.25% of the regional population "Central and NE Europe/Black Sea and Mediterranean" [37]. The Common Pochard was present in 809 counts and absent in 991 counts (no observed birds during visits), while 2.640 data are missing (the unavailable records relative to the species' known wintering sites, which have not been visited during certain years) (Table S1). Its population trend (Figure 1) is stable in the long term (additive slope = -0.0101 ± 0.0057 ; multiplicative slope = 0.9900 ± 0.0057), a significant moderate decline in the medium term (additive slope = -0.0727 ± 0.0117 ; multiplicative slope = 0.9299 ± 0.0109 ; $p < 0, 01$), and uncertain in the short term (additive slope = -0.0226 ± 0.0279 ; multiplicative slope = 0.9776 ± 0.0273), but with a declining tendency. This decline is more evident during the last decade (2010–2019) even though the census effort has significantly increased.

The Marbled Teal's national average is almost the same, in the long term (3.071) and short term (3.070).

However, this number hides very high interannual fluctuations (Figure 2), knowing that the total annual numbers vary between 27 (in 1996) and 3.755 ducks (in 2013). Morocco hosts 47% of the regional population "West Mediterranean/West Mediterranean and West Africa" [37]. The species was present in 295 counts and absent in 651 counts (no observed birds during visits), while 904 data are missing (Table S2). Its population trend (Figure 2) is stable in the long term (additive slope = -0.0050 ± 0.0092 ; multiplicative slope = 0.9950 ± 0.0092), whilst it is uncertain in the medium term (additive slope = -0.0208 ± 0.00169 ; multiplicative slope = 0.9794 ± 0.0166) and short term (additive slope = 0.0097 ± 0.0447 ; multiplicative slope = 1.0097 ± 0.0452).

The White-headed Duck's national average is 445 between 2005 and 2019 and 542 individuals during the last decade (2010–2019). Morocco hosts 22% of the regional population "Spain and Morocco" [37]. The observed total annual numbers varied between 1 and 1.730 (Figure 3). The species was observed, in the context of IWC, during the period 2005–2019 and was present in 29 counts and absent in 58 counts (no observed birds during visits), while 45 records are missing (Table S3). The population's trend (Figure 3), for the 2005–2019 period, is a moderate increase (additive slope = 0.2749 ± 0.1181 ; multiplicative slope = 1.3164 ± 0.1554 ; $p < 0, 05$). In the short term, it is uncertain (additive slope = 0.3899 ± 0.4609 ; multiplicative slope = 1.4768 ± 0.6807), but with an increasing tendency.

3.2. Spatial Distribution. The Common Pochard was observed in a total of 118 wetlands (43% of the surveyed wetlands) (Table S1), mostly in the Northern half of the country, along the Atlantic coast and Atlas region (Figure 4). However, from year to year, the species was reported in 9 to 39 sites (Figure 1). Between 2010 and 2019, the northwest (31 sites) and northeast (16 sites) regions hosted the highest concentrations (37% and 33%, respectively). Amongst the sites visited at least 19 winters over the 37 years study period, the species occurrence percentage was the highest in five of them (>85%): "Aguelmam Abekhane," "Aguelmam Afen-nourir," "Merja de Sidi Bou Ghaba," "Dayet Ifrah" and "Barrage de Smir." The highest total numbers (between 1983 and 2019) were cumulated as follows: "Barrage Mohammed V," "Barrage Al Massira," and "Embouchure de Wad Massa." In the short term (amongst the sites visited at least 5 years out of 10), the highest average numbers were recorded in "Barrage Mohammed V" and "Merja de Sidi Bou Ghaba" (Table 2). Some wetlands have known a decline in the species' wintering numbers, such as "Embouchure de Wad Massa;" others such as "Merja de Fouwarate" have hosted increasing numbers in recent years. The highest concentration ever recorded in Morocco (15.600 birds) was observed in the reservoir of "Barrage Mohammed V" in 2002. This site has known high fluctuations of the Common Pochard's numbers (zero to thousands), which is clearly reflected by its high standard deviation (Table 2).

The Marbled Teal was observed in a total of 50 wetlands (18% of the surveyed wetlands) (Table S2), mainly

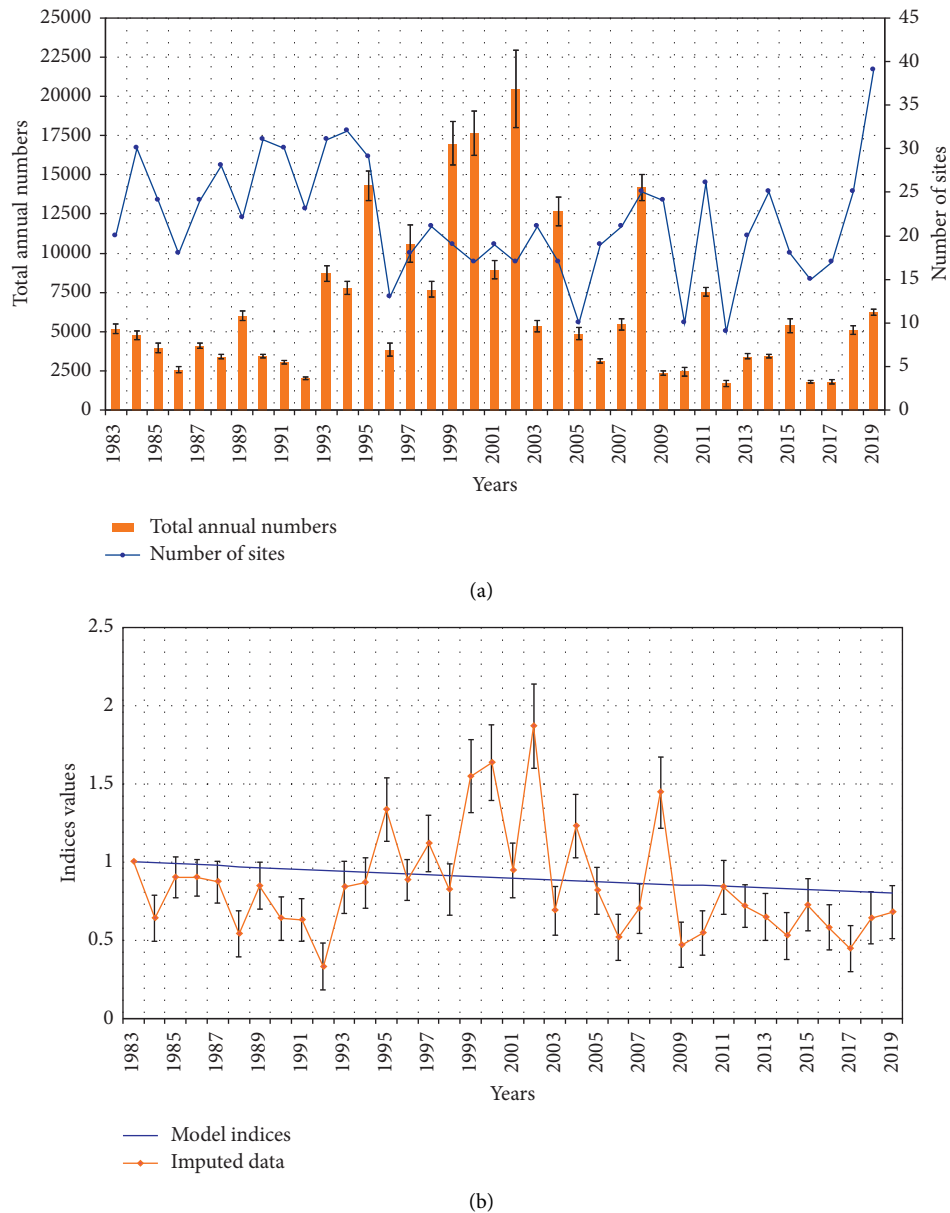


FIGURE 1: (a) Total annual numbers of the Common Pochard and number of wetlands where it has been observed in Morocco between 1983 and 2019. (b) Linear trend of the wintering population (TRIM analysis).

distributed north and west to the Atlas Mountains and in the northern part of the Sahara (Figure 5). Annual distribution varied between 2 and 19 sites (Figure 2). In the short term, 67% of the national average was observed in the southern region (in 15 wetlands), with particularly high concentrations in 2013 (95%) and 2018 (62%). The other regions hosted 8% to 15% of this number. The highest occurrence of the species was recorded in “Merja de Sidi Bou Ghaba” (97% of the visits), “Lagunes de Sidi Moussa-Walidia” (83%), and “Embouchure de Wad Massa” (81%). Three sites hosted each, more than 10% of the total numbers recorded between 1983 and 2019: “Lagunes de Sidi Moussa-Walidia,” “Wad As-Saqia Al Hamra à La’youn,” and “Merja de Sidi Bou Ghaba.” The highest standard deviations were recorded in two sites (Table 3):

- (i) “STEU Guelmim”: a wastewater treatment plant, only visited in 2016 (89 ducks) and in 2018 during which a high concentration of 1.748 was recorded.
- (ii) “Was As-Saqia Al Hamra à La’youn”: observations varied between 0 individuals and the highest concentration ever recorded in Moroccan sites (3.557, almost half of the national population in 2013).

Since its reappearance in Morocco in the early 2000s, the White-headed Duck was observed in 12 wetlands (17% of the surveyed wetlands), mainly in the north of the country (Table S3; Figures 3 and 6). Its annual distribution did not exceed six sites, and it was not observed in any wetland visited in 2006, 2007, 2010, and 2012 (Figure 3). Most of its population is located in the northwest region (73%). The

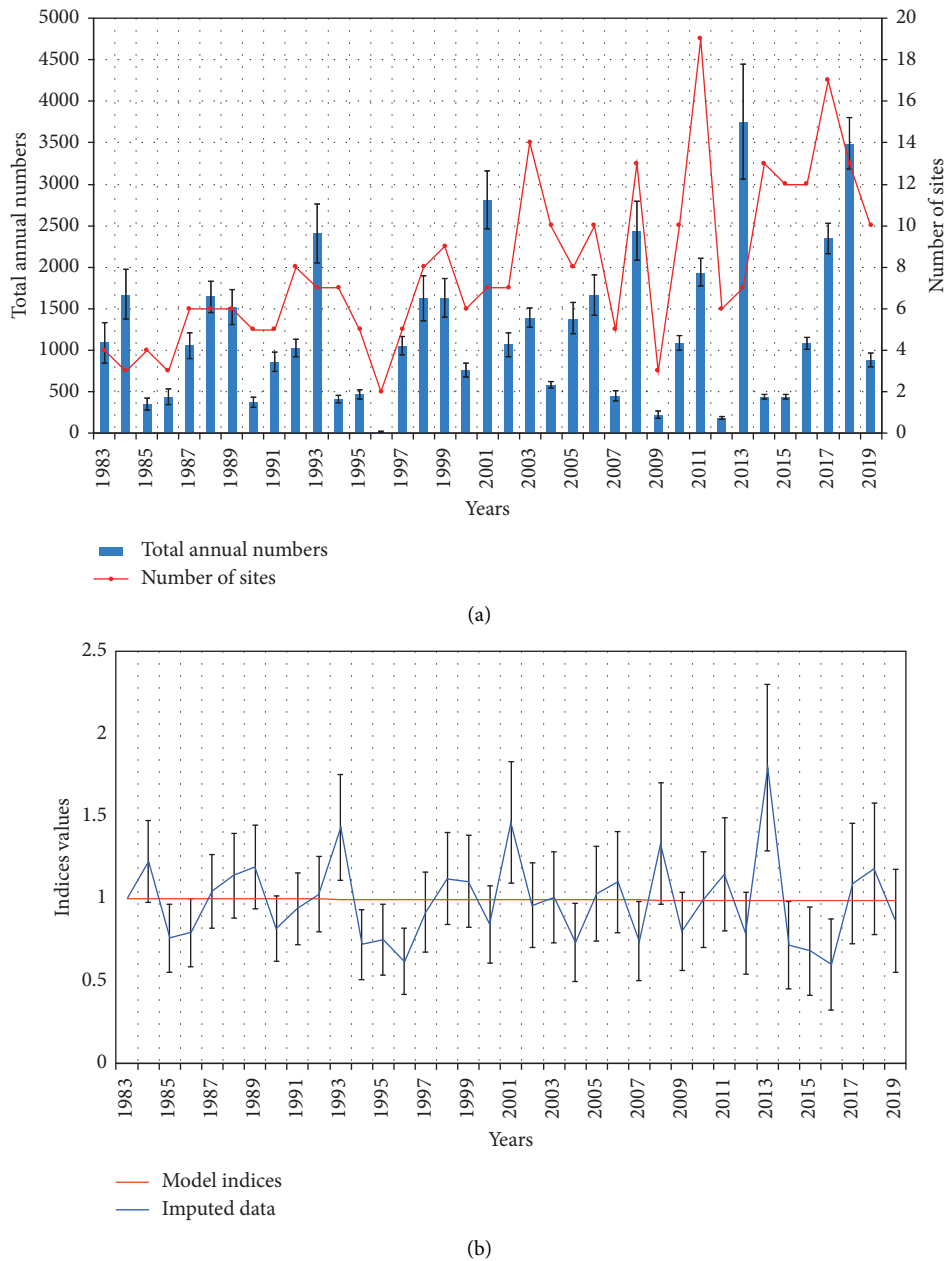
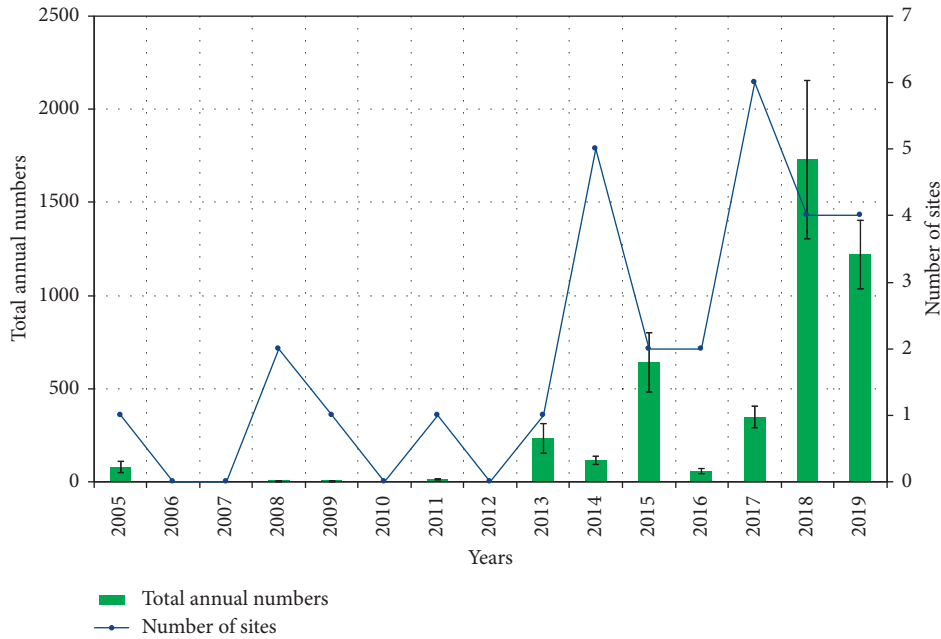


FIGURE 2: (a) Total annual numbers of the Marbled Teal and the number of wetlands where it has been observed in Morocco between 1983 and 2019. (b) Linear trend of the wintering population (TRIM analysis).

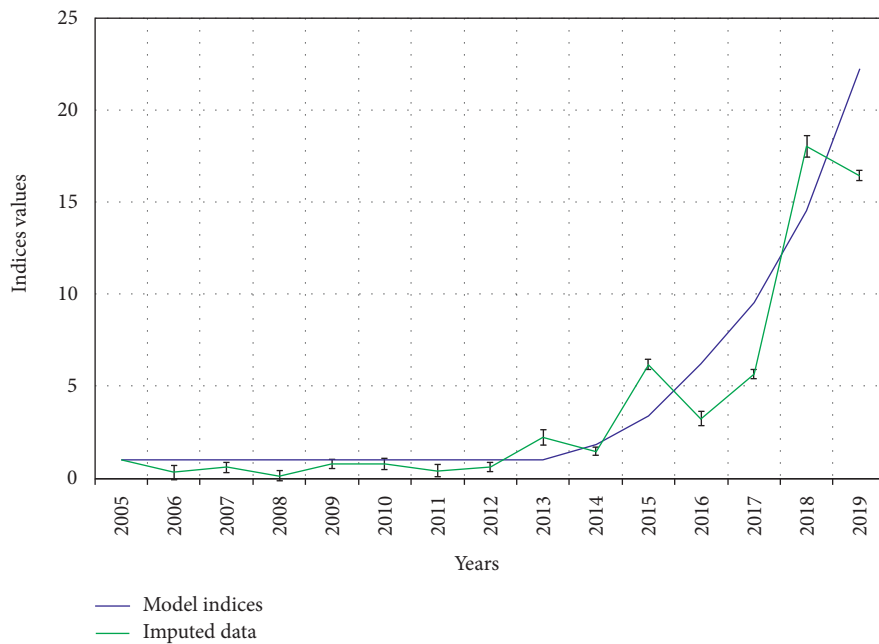
species was most regular in “Merja de Sidi Bou Ghaba” (75% of the visits) and “Merja de Fouwarate” (45%). Three wetlands (“Merja de Fouwarate,” “Merja de Sidi Bou Ghaba,” and “Barrage Mohammed V”) hosted more than 10% of the wintering individuals. It is worth mentioning that the wetland “Plan d’eau de Dwyate” is hard to access, since it is part of a royal domain. Except for a temporary lake on the east (suffering from some disturbance, overgrazing, and recurrent droughts [29]), it is fenced and well-guarded and hence with no disturbance, which makes it a site of great importance for the species. The highest standard deviation was recorded in “Merja de Fouwarate” (Table 4), where the species was not observed before 2014 (Table S3) and where

the highest concentrations nationally were recorded (1.430 in 2018 and 500 in 2019).

3.3. Sites of International and National Importance. The Common Pochard is a globally vulnerable species, which makes all the sites hosting it of international importance (SII2 as we have defined in Methodology). None of the Moroccan wetlands verify the Ramsar criterion 6 for the species. Nevertheless, it is worth mentioning that “Barrage Mohammed V” could be of potential international importance. In fact, in 2002, this site hosted a high concentration of 15.600 ducks, which exceeded the estimated 1% of the



(a)



(b)

FIGURE 3: (a) Total annual numbers of the White-headed Duck and the number of wetlands where it has been observed in Morocco between 2005 and 2019. (b) Linear trend of the wintering population (TRIM analysis).

regional population at the time (10.000) [37]. The reported species' numbers in this wetland can be highly underestimated due to a difficult access to many parts of the reservoir, depending on the conditions. Therefore, it can, more than likely, host regularly at least 1% of the Common Pochard's regional population. This could also be the case for "Barrage Al Massira," a reservoir often partially censused and which hosted, in 2008, 5.500 ducks. Among the 118 wetlands where the species was observed, 26 have average numbers equal or superior to 1% the national average

(7.496) (Table 2), which makes them of national importance. On the contrary, 15 others hosted wintering numbers exceeding that threshold, during at least one winter (Table 2), which makes them of potential national importance.

The Marbled Teal is a globally vulnerable species, which makes all the sites hosting it of international importance as well (SII2). Moreover, 18 wetlands hosted, at least once, more than 1% of the regional population [5], three of them regularly: "Lagunes de Sidi Moussa-Walidia," "Merja Zerga," and "Wad As-Saqia Al Hamra à La'youn;" they are thus of international

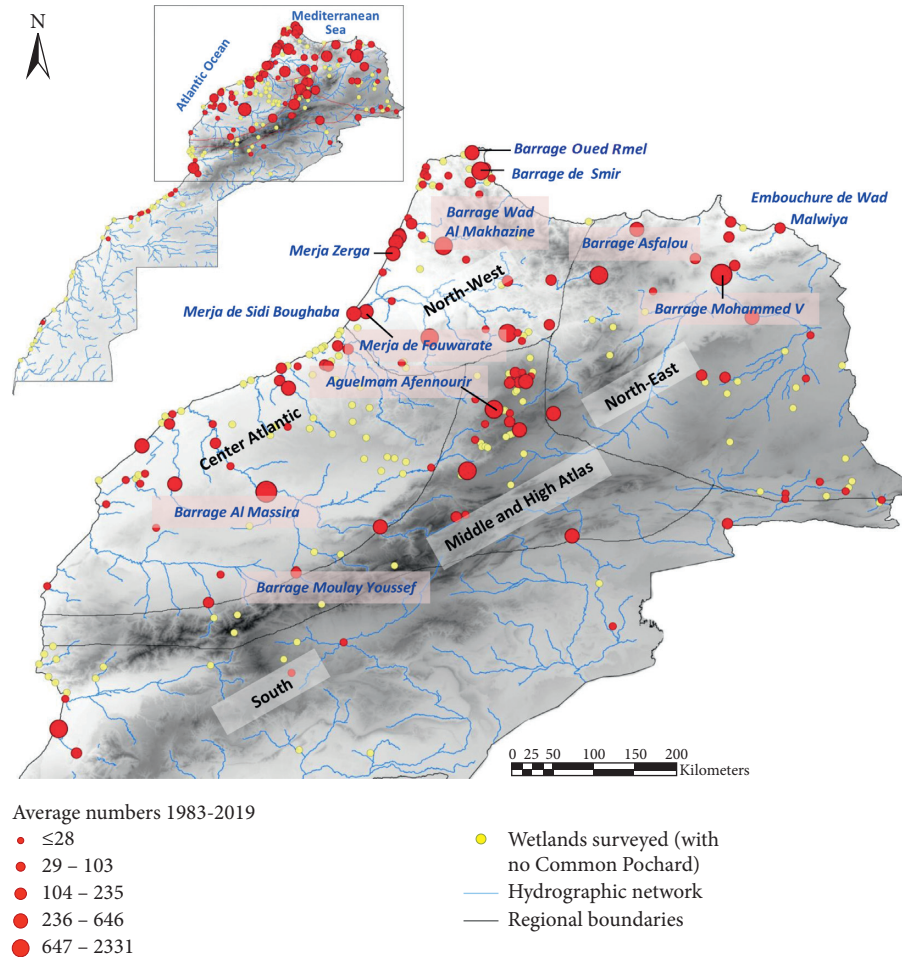


FIGURE 4: Distribution map of the Common Pochard's wintering population in Morocco (1983–2019).

importance for the species (SII1) (Table 3). On the contrary, 26 wetlands have average numbers equal or superior to 1% of the national average (Table 3), which makes them of national importance. Among them, 11 hosted wintering numbers exceeding that threshold during at least one winter (Table 3), which makes them of potential national importance.

Because it is endangered, the White-headed Duck attributes an international importance to all the 12 sites hosting it (SII2). The 1% of the regional population [37] was exceeded, at least one winter, in five wetlands, but regularly in “Merja de Sidi Bou Ghaba” and “Merja de Fouwarate.” On the contrary, seven wetlands hosted, at least once, more than 1% of the national average, cumulating 99.8% of this number. Among them, 6 are of national importance and one is of the potential national importance (Table 4).

For the three species, some sites need to be monitored more regularly to verify and/or confirm their national/international importance since they have been visited less than 5 winters (Tables S1–S3).

3.4. Current Conservation Measures in Morocco towards the Three Species. An efficient legal conservation way consists in classifying a bird in an official list of protected species. Two

main lists exist in the Moroccan legislation: a list of species for which hunting is banned (published through the “Annual Hunting Order”) and a list of species in which trade and transport is conditioned by a special governmental authorization (through the CITES Law “N°29–5”). The hunting of the White-headed Duck and Marbled Teal is prohibited in Morocco, whilst the Common Pochard can still be hunted [38].

National action plans for species can also be efficient tools for the conservation of birds and their habitats. In Morocco, only the White-headed Duck has a national action plan [18].

In situ conservation mechanisms represent another important measure for the conservation of the three species. In addition to two international statuses for the conservation of wetlands: (i) Ramsar Sites and Important Bird and Biodiversity Areas (IBA), these mechanisms also consist, in Morocco, in the creation of three national statuses for which a high number of wetlands have been designated for. Several bird species, including the three ducks subject of this article, have been targeted by these statuses: (i) national parks (NPs); (ii) Sites of Biological and Ecological Interest (SBEI), defined in 1996 [39], with at least 84 wetlands, partly assessed using waterbirds; and (iii) permanent hunting reserves (PHRs).

The Common Pochard is found in 44 wetlands, with at least one conservation status (Table 5); 22 of them are Ramsar sites,

TABLE 2: Most important wintering sites of the Common Pochard (2010–2019).

Site name	Average number ¹	Max. ²	1% NA ³	Importance	Standard deviation
Barrage Hassan Ad-Dakhil	850	1700	1	SNI/SII2	530
Barrage Mohammed V	626	15600	2	SNI/SII2	3816
Merja de Sidi Bou Ghaba	514	1200	8	SNI/SII2	258
Aguelmam Afennourir	468	2600	4	SNI/SII2	624
Merja de Wad Fouwarate	413	1000	8	SNI/SII2	308
Barrage Wad Al Makhazine	317	1101	3	SNI/SII2	345
Barrage de Smir	312	1689	4	SNI/SII2	462
Sadd Al Ajras	305	305	1	SNI/SII2	98
Barrage Asfalou	300	300	1	SNI/SII2	0
Aguelmam Abekhane	296	855	2	SNI/SII2	200
Barrage Al Massira	256	7038	3	SNI/SII2	1853
Aguelmam N'Tifounassine	227	652	1	SNI/SII2	145
Merja Zerga	210	1800	2	SNI/SII2	324
Barrage Hassan II	186	1100	2	SNI/SII2	327
Dayet Ifrah	180	860	3	SNI/SII2	218
Aguelmams Sidi Ali-Ta'nzoult	172	1700	4	SNI/SII2	360
Barrage Mechra' Hommadi	126	290	2	SNI/SII2	82
Barrage Enjil	124	690	3	SNI/SII2	179
Barrage Oued Rmel	124	160	2	SNI/SII2	37
Dayet 'Awa	122	1030	3	SNI/SII2	192
Embouchure de Wad Malwiya	104	224	5	SNI/SII2	67
Barrage Moulay Youssef	94	114	1	SNI/SII2	43
Merja Bargha	89	1590	4	SNI/SII2	323
Marais de Wad Smir	87	391	3	SNI/SII2	83
Barrage Sahla	85	164	1	SNI/SII2	80
Barrage Al Wahda	84	283	1	SNI/SII2	117
Barrage Hassar	74	148	3	SPNI/SII2	60
Mlalah du Bas Tahaddart	69	480	1	SPNI/SII2	96
Barrage Kheng El Hda	67	200	4	SPNI/SII2	61
Barrage Petit Tizil	52	250	2	SPNI/SII2	79
Dayet Hachlaf	45	163	1	SPNI/SII2	56
Barrage Zelmou	38	159	1	SPNI/SII2	44
Barrage Arabat	38	94	1	SPNI/SII2	40
Barrage Idriss Premier	34	570	1	SPNI/SII2	156
Marais du bas Loukkos	34	410	1	SPNI/SII2	83
Merja des Wlad Khallouf	30	240	1	SPNI/SII2	53
Merja Al Halloufa	25	680	2	SPNI/SII2	220
Embouchure de Wad Massa	23	3330	1	SPNI/SII2	832
Merja des Wlad Skher	23	650	2	SPNI/SII2	143
Lagunes de Sidi Moussa-Walidia	16	2500	1	SPNI/SII2	431
Sebkha Bou Areg	12	406	1	SPNI/SII2	109

¹The average (mean) of the species' annual numbers counted in a site (their sum is divided by the number of years the site was censused). ²Maximum wintering number observed in a site since its first year of census. ³Number of winters during which 1% of the national average (7.496) is exceeded.

34 are SBEI, 21 are IBA, 9 are part of national parks, and 18 are part of permanent hunting reserves. The Marbled Teal occupies 25 wetlands having national and/or international conservation statuses: 15 Ramsar sites, 20 SBEI, 16 IBAs, 3 are part of national parks, and 10 are part of permanent hunting reserves. Among the 9 wintering wetlands of the White-headed Duck with conservation statuses, 6 are Ramsar sites, 7 SBEI, 5 IBA, 3 are part of national parks, and 5 are part of permanent hunting reserves.

4. Discussion

4.1. Population Size and Trend. The global population of the Common Pochard is considered to be decreasing [8]. Even

though regional populations' trends differ from stable to unknown [8], the European population, which represents 35% to 40% of the global population, has decreased by 30–49% over three generations [8, 40, 41].

The Moroccan wintering numbers show a significant decline, especially during the two recent decades, which could be directly linked to the declining trend of the regional population "Central and NE Europe/Black Sea and Mediterranean" [37, 42–44], from which the wintering individuals in Morocco originate. In fact, according to the IUCN [37], the species' decrease is mainly due to the loss of its breeding habitat in Eastern Europe. In Central Europe, it appears that the major factors responsible for its decline are nest predation [37, 45] by natural (*Vulpes vulpes* and *Sus*

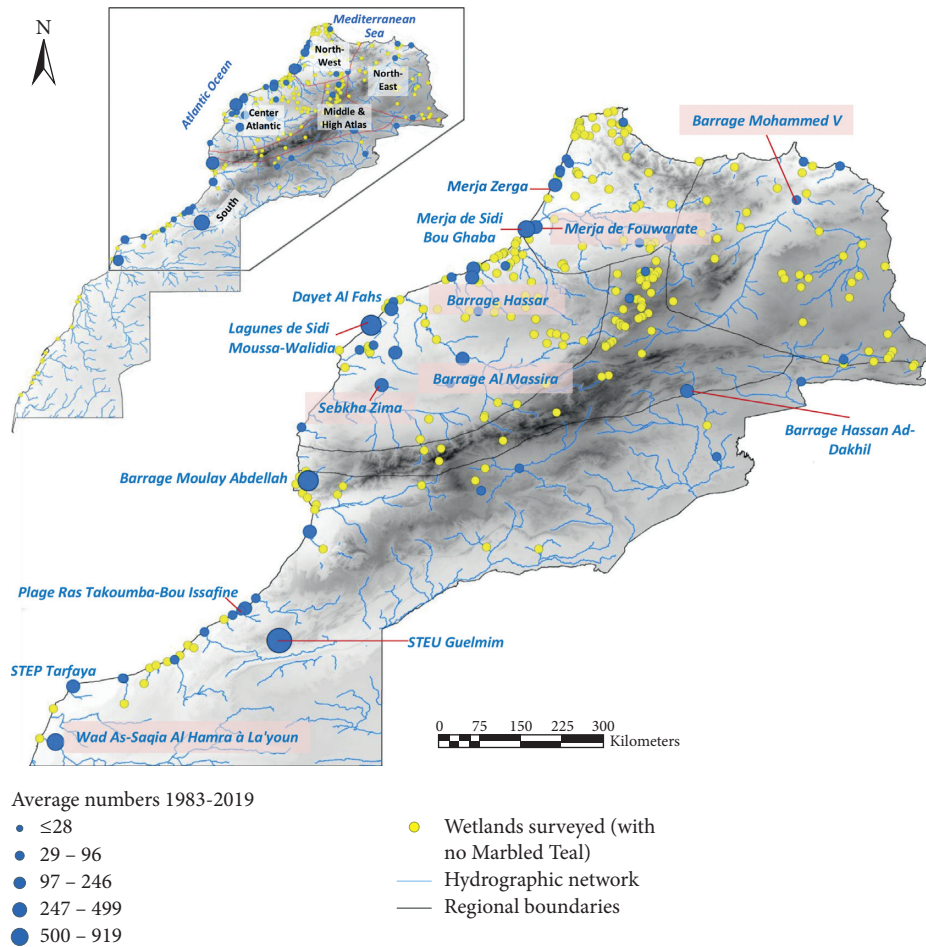


FIGURE 5: Distribution map of the Marbled Teal's wintering population in Morocco (1983–2019).

scrofa) and alien mammal species (i.e., *Neovison vison*, *Nyctereutes procyonoides*, and *Procyon lotor*) and a decline of *Dreissena polymorpha*, the zebra mussel which is the preferred food of this duck [46–48]. Furthermore, Fox et al. (2016) [41] have summarized multiple factors influencing the breeding population in the old continent; they are mostly related to loss or changes in habitats, food availability, predation, alien species, hunting [9, 49, 50], fishing, disturbance, and lead poisoning [51]. On the contrary, Folliot et al. (2018) [52] suggest that decreasing wintering numbers in Western Europe can also be due to the decline of the breeding population in the southwest Asian flyway (especially in Siberia). In fact, analyses of ringing recoveries data showed that large wintering numbers in the northwest European flyway originate from the southwest Asian flyway, which brings to evidence the interactions and exchange between the different regional populations beyond the determined limits of the flyways. In addition to the aforementioned factors that are possibly contributing to the decline of the Common Pochard in Morocco, climate change can also play a crucial role in the species' populations changes [53–58] at a larger scale, as well as the direct threats faced by the species in Moroccan wetlands.

The evolution of the Marbled Teal's wintering population in Morocco is consistent with the trend of the

regional population (West Mediterranean/West Mediterranean and West Africa), which is stable [42], but with a possible declining tendency [37]. The global population of the species has decreased rapidly overtime [7]; only the southwest Asian population knows a possible increase [37], albeit it may be due to an improvement in census coverage instead of actual changes within the population [7].

In Morocco, the Marbled Teal's population often showed a lot of fluctuations from one year to another. In fact, the species can have extreme fluctuations in its population's size depending on rainfall's annual variation [18]. It can therefore relocate to other areas that may be unmonitored and vice versa and hence giving the impression of an increase or decrease in numbers. This relocation could occur between wetlands of the same country as well as at a larger scale, between wintering areas of different countries. Moroccan wintering individuals can come from breeding sites in Europe (e.g., Spain) and North Africa [59] (especially Algeria, which hosts important numbers of the species [60–62]). Nevertheless, the high records observed sometimes are not necessarily caused by an influx from Spain but could be explained by the presence of unknown breeding sites of great importance in the country or in North Africa [59]. The sometimes declining numbers of the species in Morocco and other regions can also be function of the habitats' quality and availability. In fact, the global population's decrease was a

TABLE 3: Most important wintering sites of the Marbled Teal (2010–2019).

Site name	Average number ¹	Max. ²	1% NA ³	Importance	Standard deviation
Wad As-Saqia Al Hamra à La'youn	448	3557	9	SIII/SNI	708
Lagunes de Sidi Moussa-Walidia	157	1800	6	SII1/SNI	471
Merja Zerga	83	200	9	SII1/SNI	49
STEU Guelmim	919	1748	2	SII2/SNI	830
Barrage Moulay Abdellah	499	997	1	SII2/SNI	499
Barrage Hassan Ad-Dakhil	188	339	2	SII2/SNI	106
Sebkha Zima	148	950	3	SII2/SNI	185
Merja de Fouwarate	119	400	7	SII2/SNI	107
Merja de Sidi Bou Ghaba	74	1400	3	SII2/SNI	302
Barrage Mohammed V	50	230	2	SII2/SNI	49
STEP Tarfaya	44	44	1	SII2/SNI	0
Dayet Al Fahs	44	636	2	SII2/SNI	125
Radier de l'Oued Assaka	43	75	2	SII2/SNI	32
Barrage Al Massira	36	1973	3	SII2/SNI	355
Barrage Hassar	36	128	2	SII2/SNI	48
Plage Ras Takoumba-Bou Issafine	31	550	1	SII2/SPNI	161
Marais de Wad Al Maleh	22	248	1	SII2/SPNI	86
Embouchure de Wad Massa	20	397	3	SII2/SPNI	101
Plage Blanche	17	136	1	SII2/SPNI	32
Embouchure de Wad Malwiya	15	142	1	SII2/SPNI	27
Embouchure de Wad Bou Issafine	13	60	1	SII2/SPNI	16
Embouchure de Wad Assaka	13	52	1	SII2/SPNI	15
Marais du bas Loukkos	11	82	2	SII2/SPNI	18
Dayet Taras El Ghoul	8	350	1	SII2/SPNI	76
Daya Al Beyda	6	37	1	SII2/SPNI	9
Barrage Zelmou	5	37	1	SII2/SPNI	11

¹The average (mean) of the species' annual numbers counted in a site (their sum is divided by the number of years the site was censused). ²Maximum wintering number observed in a site since its first year of census. ³Number of winters during which 1% of the national average (3.070) is exceeded.

direct consequence of habitats' loss and degradation [7, 59, 63] due mainly to drainage of wetlands for agricultural purposes and hydrological work [7]. In our country, for example, one of the most important breeding sites, the Iriki Lake (where the Marbled Teal used to breed in high numbers (hundreds of couples in the 1960s)), has disappeared because of the construction of a dam (Barrage Al Mansour Ad-Dahbi) [24]. Although this vulnerable duck is legally protected in Morocco [24], it still faces many threats affecting negatively its population. These threats are mainly related to human activities, disturbing, degrading, or destructing its habitats, and changes in water levels (caused by low precipitations, drainage, and hydraulic work). In fact, the species' wetlands occupancy in our country, especially in the breeding season, is closely dependent on habitat-related factors, such as the number and diversity of emergent vegetation species [22, 64, 65], which are more predominant in Ramsar sites close to the coastline [65].

Since its return in Morocco, the White-headed Duck's population has known a moderate increase. Notwithstanding, the global population of the species is thought to be decreasing [6]. This decline is estimated to be 50–79% in three generations [6] even though many subpopulations are not thoroughly recorded, which may lead to an underestimation of the species counts [6, 66]. The increase in this endangered duck's population in Morocco, especially the high numbers recorded in "Merja of Fouwarate" during the 2018 winter (1.430 individuals) [30], could

have different potential explanations and combined factors:

- (i) A flow of migrants from Spain: the conservation and protection efforts undertaken by Spain, over more than 30 years [29], have had a strong positive effect on the White-headed Duck's population in Spain and may have contributed to its return to Morocco and its increasing numbers in the country [29].
- (ii) A flow of individuals from the regional population of "Algeria and Tunisia," which hosts significant breeding numbers of the White-headed Duck [66]. There are, currently, insufficient data to decide if there is any exchange between the West Mediterranean and North African subpopulations [66] that could also contribute to the species increase in Morocco. Nevertheless, our country is at an advantageous position between the increasing Spanish population and the Algerian one, which hosts high numbers of the species during the breeding season and throughout the year [66–70], but faces many threats in the country, especially illegal killing [71].
- (iii) The decline in the population of the ruddy duck and its hybrids due to campaigns for its eradication in Spain, Europe [29, 72], and Morocco [73].
- (iv) The presence of favorable breeding sites in Morocco, thanks to wetlands conservation efforts and

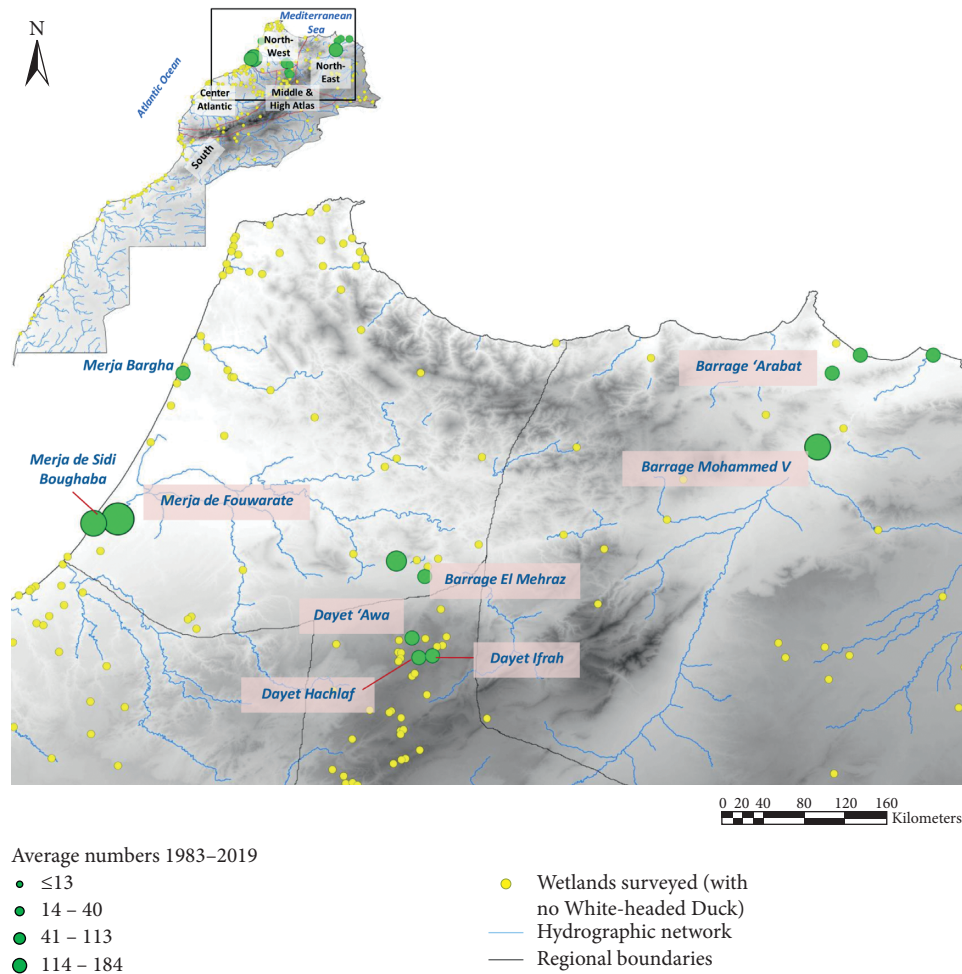


FIGURE 6: Distribution map of the White-headed Duck's wintering population in Morocco (2005–2019).

TABLE 4: Most important wintering sites of the White-headed Duck (2010–2019).

Site name	Average number ¹	1% NA ²	Max. ³	Importance	Standard deviation
Merja de Sidi Bou Ghaba	170	8	351	SIII/SNI	120
Merja de Wad Fouwarate	225	5	1430	SII2/SNI	419
Barrage Mohammed V	106	3	426	SII2/SNI	145
Dayet Ifrah	15	2	59	SII2/SNI	19
Dayet Hachlaf	15	1	88	SII2/SNI	31
Barrage 'Arabat	9	2	22	SII2/SNI	9
Barrage El Mehraz	2	1	6	SII2/SPNI	3
Dayet 'Awa	1	0	3	SII2	1

¹The average of the species' annual numbers counted in a site (their sum is divided by the number of years during which the site was censused). ²Maximum wintering number observed in a site since its first year of census. ³Number of winters during which 1% of the national average (542) is exceeded.

suitable climate conditions that contribute to good water levels [74] and more developed vegetation cover.

In Morocco, many factors have contributed to the former disappearance of this endangered duck and halted its expansion. Overgrazing and repeated cutting of reed beds caused a regression of emergent vegetation in permanent wetlands [29], which is crucial for this duck's breeding. According to El Hamoumi et al. [31], the species still faces

many other threats; the most imminent one is the hybridization with the ruddy duck. In fact, this introduced species has been observed in Morocco on many occasions, and the last documented observation was in 2013, where 2 individuals were observed in Merja Al Halloufa [75]. Nevertheless, unpublished data (Hassani H. and Dakki M. in litt.) have reported the ruddy duck, during recent years in Barrage Al Mehraz in 2014 and 2015, one of the sites where breeding White-headed Ducks have been observed [31]. The second most imminent threat to the survival of the species in

TABLE 5: Conservation statuses of the three species' hosting wetlands.

Site name	Types of habitat	Region	Ramsar	IBA ¹	SBEI ²	NP ³	PHR ⁴	Aytfer ⁵	Marang ⁶	Oxyleu ⁷
Aguelmam Abekhane	Inland lake	Atlas	—	—	X	—	—	X	—	—
Aguelmam Afennourir	Inland lake	Atlas	X	—	X	I ¹²	X	X	X	—
Aguelmam Azegza	Inland lake	Atlas	—	—	X	—	—	X	—	—
Aguelmam N'Tifounassine	Inland lake	Atlas	X	X	X	I ¹²	X	X	—	—
Aguelmam Wiwane	Inland lake	Atlas	—	—	X	—	—	X	—	—
Aguelmams Sidi Ali-Ta'nzoult	Inland lake	Atlas	—	X	X	—	—	X	—	—
Baie d'Ad-Dakhla ^(a)	Bay	South	X	X	X	D ¹³	—	X	—	—
Barrage Al Mansour Ad-Dahbi ^(b)	Artificial reservoir	South	—	X	X	—	—	X	X	—
Barrage Al Massira ^(b)	Artificial reservoir	Center Atlantic	X	X	X	—	X	X	X	—
Barrage de Wad Al Mellah ^(b)	Artificial reservoir	Center Atlantic	—	—	X	—	—	X	—	—
Barrage de Smir ^(b)	Artificial reservoir	Northwest	X ⁸	—	—	—	—	X	—	—
Barrage Idriss Premier ^(b)	Artificial reservoir	Northwest	—	X	X	—	—	X	X	—
Barrage Mohammed V ^(b)	Artificial reservoir	Northeast	X	X	X	—	X	X	X	X
Côte et Archipel d'Essawira ^(c)	Coastal wetland	Center Atlantic	X	X	X	—	—	X	X	—
Dayet Ar-Roumi	Inland lake	Northwest	—	—	X	—	—	X	—	—
Dayet'awa	Inland lake	Atlas	X ⁹	—	X	I ¹²	X	X	X	X
Dayet Hachlaf	Inland lake	Atlas	X ⁹	—	—	I ¹²	X	X	—	X
Dayet Ifrah	Inland lake	Atlas	X ⁹	—	X	I ¹²	X	X	—	X
Embouchure de Wad Al Wa'er ^(d)	River mouth	South	—	—	X	—	—	X	—	—
Embouchure de Wad Assaka ^(d)	River mouth	South	—	—	X	—	X	X	X	—
Embouchure de Wad Chbeyka ^(d)	River mouth	South	—	X	X	—	X	X	X	—
Embouchure de Wad Dr'a ^(d)	River mouth	South	X	—	X	—	—	—	X	—
Embouchure de Wad Malwiya ^(d)	River mouth	Northeast	X	X	X	—	—	X	X	X
Embouchure de Wad Martil ^(d)	River mouth	Northwest	—	X	—	—	—	X	—	—
Embouchure de Wad Massa ^(d)	River mouth	South	X	—	—	SM ¹⁴	X	X	—	—
Lac de Tislite ^(e)	Inland lake	Atlas	X	—	X	HAO ¹⁵	—	X	—	—
Lac d'Isly ^(e)	Inland lake	Atlas	—	—	X	HAO ¹⁵	—	X	—	—
Lagune de Khnifiss ^(f)	Lagoon/ marshland	South	X	X	X	K ¹⁶	—	—	X	—
Lagunes de Sidi Moussa-Walidia ^(f)	Lagoon/ marshland	Center Atlantic	X	X	X	—	X	X	—	—
Marais de Wad Al Maleh ^(g)	Marshland	Center Atlantic	X	—	—	—	—	X	X	—
Marais de Wad Smir ^(g)	Marshland	Northwest	X ⁸	—	—	—	—	X	X	—
Marais du bas Loukkos ^(g)	Marshland	Northwest	X	—	—	—	—	X	X	—
Merja Al Halloufa	Marshland	Northwest	X ¹⁰	X	X	—	—	X	—	—
Merja Bargha	Marshland	Northwest	X ¹⁰	X	—	—	—	X	X	X
Merja Boukka	Marshland	Northwest	—	—	X	—	X	X	—	—
Merja de Fouwarate	Marshland	Northwest	X	—	X	—	—	X	X	X
Merja de Sidi Bou Ghaba	Marshland	Northwest	X	X	X	—	X	X	X	X
Merja des Wlad Khallouf	Marshland	Northwest	—	—	—	—	X	X	—	—
Merja des Wlad Skher	Marshland	Northwest	X ¹⁰	—	X	—	—	X	X	—
Merja Zerga	Marshland	Northwest	X	X	X	—	X	X	X	—
Mlalah du Bas Tahaddart	Marshland	Northwest	X	X	X	—	X	X	—	—
Plan d'eau de Dwiya ^(h)	Inland lake	Northwest	—	X	X	—	—	X	X	X
Plan d'eau de Zerrouqa ^(h)	Inland lake	Atlas	X ¹¹	—	X	—	—	X	—	—
Sebkha Bou Areg	Lagoon	Northeast	—	X	X	—	X	X	X	—
Sebkha Zima	Saline lake	Center Atlantic	—	X	X	—	X	X	X	—
Sehb El Mejnoun	Depression wetland	Center Atlantic	—	X	X	—	—	—	X	—
Wad As-Saqia Al Hamra à La'youn	River	South	X	X	—	—	—	X	X	—

^(a)Baie = bay; ^(b)Barrage = dam; ^(c)Côte = coast; Archipel = archipelago; ^(d)Embouchure = river mouth; ^(e)Lac = lake; ^(f)Lagune = lagoon; ^(g)Marais = marsh; ^(h)Plan d'eau = waterbody. ¹Important bird and biodiversity areas; ²Sites of Biological and Ecological Importance; ³national parks; ⁴permanent hunting reserves; ⁵Common Pochard (*Aythya ferina*); ⁶Marbled Teal (*Marmaronetta angustirostris*); ⁷White-headed Duck (*Oxyura leucocephala*); ⁸Ramsar site: "Lagune et barrage de Smir;" ⁹Ramsar site: "Lacs d'Imouzzur du Kandar;" ¹⁰Ramsar site: "Marais et Côte du Plateau de Rmel;" ¹¹Ramsar site: "Oued Tizguite;" ¹²Ifrane National Park; ¹³Dakhla National Park (project); ¹⁴Souss-Massa National Park; ¹⁵Haut Atlas Oriental National Park; ¹⁶Khnifiss National Park.

Morocco is the excessive pumping [31], from artificial and natural wetlands, as well as groundwater. This leads to lower water levels or even the drying-out of the wetlands, making it difficult for the species to thrive in such conditions. The other threats are mainly related to different disturbances that can affect the species population directly (illegal or accidental hunting and stray dogs that feed on ducklings or eggs) or indirectly (recreational activities and inadequate management policies).

Most of the key wintering wetlands of the three waterfowls benefit from at least one conservation status. The attribution of these conservation statuses represents an important step in their conservation. In fact, some of these sites also have management plans that allow enhanced land and water management and the protection against anthropogenic threats. This begs the following question: if the most important sites for the species benefit from conservation statuses and measures, on what scale should we also focus to improve the populations' size?

4.2. Conservation Stakes. For each of three species presented in this article, the population changes are often multifactorial and can be in situ or ex situ. In fact, these ducks are highly dependent on their habitats, especially during the breeding season. As we have discussed above, any negative change, be it natural (e.g., drought and flood) or anthropogenic (e.g., drainage, vegetation cutting, and hydraulic work) can potentially result in their decrease or redistribution to other sites. The designation of Ramsar and important bird and biodiversity sites is one of the important measures for the waterbirds and wetlands conservation and among the good indicators of its success. In Morocco, 49 wetlands are important bird biodiversity areas, 38 are Ramsar sites, and at least 84 are Sites of Biological and Ecological Interest (SBEI), among which many are part of national parks and/or permanent hunting reserves. While these statuses are important, if no ensuing effective management plans are developed and implemented, their degradation, thus their biodiversity's decline, is an inevitable consequence, especially for those subject to many anthropogenic pressures. The Moroccan Department of Water and Forestry has developed management plans for many wetlands: some are finalized, and others are still in progress. The implementation of these plans can face many challenges inherent to the multiplicity of actors involved and the co-operation of the local populations, whose livelihoods may depend on the ecosystem services those wetlands provide. The designation of SBEI in Morocco was a strategic measure and a starting point to prioritize the conservation of the ecosystems with the highest biodiversity indices and hosting the most endangered, rare, or endemic species. But as we have pointed out above, the implementation of management and conservation action plans remains crucial.

On the species' level, the adoption of the National Law N°29-05, enforcing the CITES Convention, is a particularly successful measure deterring all illegal actions threatening endangered species. Furthermore, the national action plan for the White-headed Duck [31] is a crucial step to the

conservation of this endangered waterbird and the restoration of a viable population on the long term. Similar actions should be undertaken for the marbled teal and the Common Pochard, as well as all globally threatened birds in Morocco, targeting the specific threats for each species in each site. However, efforts must be deployed for a rigorous implementation of these conservation action plans and their evaluation on a regular basis. While the hunting of the White-headed Duck and the Marbled Teal is prohibited, the Common Pochard can still be hunted. Given the current trend of this duck's population, at the national and international levels, more restrictions should be placed on its hunting.

So far, we have discussed the populations' changes inherent to factors at the national level. However, some of these changes can be related to factors at a larger scale and outside the national territory (e.g., threats and conservation measures in other countries). Furthermore, climate change and meteorological conditions can also have an impact on the national population. Kleijn et al. [76] have, for example, reported a positive correlation between waterbirds' population trends in Morocco and precipitations in the Sahel zone that may have a potential impact on birds' migratory strategies. Therefore, some populations' changes are probably more related to shifts in migratory routes and wintering areas than actual changes in birds' numbers [76].

More thorough research could lead to the exact reasons behind the three studied ducks' populations' trends. Comprehensive studies should be conducted to understand the effects of ecological and anthropogenic factors on the distribution, abundance, and population dynamics of waterbirds' species [12], such as water quality, food availability, predation, weather, and conservation statuses. Furthermore, with the increasing challenges that may hinder our monitoring programs [77] and the effectiveness of conservation plans, we must develop new effective methods for waterbirds' census (wintering and breeding populations) with more precision and coverage, coupled with other programs such as ringing-recovery/capture-recapture, continent/flyway, or region-wide series of aerial survey transects as has been suggested by Fox et al. (2019) [77]. This is crucial since the movements occurring within and between the regional populations of the species are still not well understood. Large-scale information on birds' populations' trends and habitats' use is insufficient, which affects negatively the conservation process [78]. Cooperative and coordinated efforts, such as the Mediterranean Waterbirds Network [79], are the key to improve data quality and quantity and to successful and adequate conservation measures, for both waterbirds and wetlands.

5. Conclusions

Through this article, we presented the current status of three globally threatened waterfowls' populations in Morocco. While the White-headed Duck's numbers are increasing and the Marbled Teal's are mostly stable, the Common Pochard has known a decline in its wintering population and its breeding range is very limited in the country.

Another important result of this synthesis is the identification of the Moroccan wetlands that play a major role as hosting key sites of the three species. These results can direct and focus the short-term conservation efforts on these key sites, to enhance the survival and thriving of these species in Morocco.

A better understanding of these ducks' populations' dynamics, which is crucial to prevent their decline, requires further studies on the ecological and anthropogenic factors influencing them. Furthermore, cooperative efforts, coupled with more effective census methods, should be carried out to enhance the knowledge on the species on the flyway/regional levels. These threatened waterbirds' survival depends, in fact, on concerted large-scale conservation measures.

Data Availability

All data generated or analyzed during this study are included in this article and its supplementary information files.

Disclosure

The funders and supporting organizations were not involved in this study's proposal, decision to publish, or writing, editing, and approval of the manuscript. The field data used in this study come from the database originating from the yearly campaigns of the waterbirds winter census in Morocco. These campaigns are conducted in the context of the IWC (International Waterbirds census), coordinated by Wetlands International. At the national level, these campaigns and the research studies (on bird species and wetlands), based on the collated data, are conducted as part of the work of the authors at the Study Center for Bird Migration, in the Scientific Institute of Mohammed V University in Rabat, Morocco. The annual campaigns have been coordinated, since 1983, by the Scientific Institute, and in recent years, the NGO "GREPOM/BirdLife Morocco" has been providing financial and technical support for the field campaigns.

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 Common Pochard's wintering individuals per year and per site. Table S2. National counts of the Marbled Teal's wintering individuals per year and per site. Table S3. National counts of the White-headed Duck's wintering individuals per year and per site. Table S4. List of observers who contributed to the IWC program in Morocco between 1983 and 2019. (*Supplementary Materials*)

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