

BREEDING BIOECOLOGY OF BARBARY FALCON *FALCO PELEGRINOIDES* (TEMMINCK, 1829) IN EL AMOUR MOUNTAINS (LAGHOuat-ALGERIA): THE FIRST STUDY IN CONTINENTAL NORTH AFRICA

Assem Zerouala^{a,d}, Mohamed Mairif^{b,d*}, Nedjla Adamou^{a,c,d}, Fatma-Zohra Nadji^e, Abderrahman Belkhir^f

^aLaghouat Forest Conservation, Algeria; ^bDepartment of Agricultural, Forestry and Environmental Sciences, Institute of Natural and Life Sciences, Ahmed Ben Yahia El-Wacharissi University, Tissemsilt, Algeria; ^cDepartment of biology, Faculty of Nature and Life Sciences, El-Oued University, 39000, El Oued, Algeria; ^dAlgerian Wildlife Watchers Association (A.W.W.A); ^eHigher Normal School, Laghouat -Algeria; ^fNational Association of Falconry

*Corresponding author. Email: mairif.mohamed@univ-tissemsilt.dz

-  Assem Zerouala: <https://orcid.org/0009-0008-7898-1466>
-  Mohamed Mairif: <https://orcid.org/0000-0002-1782-8539>
-  Nedjla Adamou: <https://orcid.org/0000-0003-1500-2319>
-  Fatma-Zohra Nadji: <https://orcid.org/0009-0009-2442-1495>
-  Abderrahman Belkhir: <https://orcid.org/0009-0008-6541-0824>

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Abstract. This work focuses on the breeding of the Barbary Falcon in the Algerian Saharan Atlas (El Amour Mountains in Laghouat province), providing new insights into the reproductive biology of this species in continental North Africa. Three nesting sites were monitored throughout 2021. All nests were located in cliff cavities at an average height of 54.6 m, more than 7 km from villages and 1.2 km from roads. Despite a small sample size ($n = 3$ broods), the average absolute fertility recorded was around 3.66 eggs per pair and the effective fertility was 11 fledglings, representing a 100% fledging success rate.

INTRODUCTION

The documentation of wild birds, particularly raptors and falcons, represents a fundamental component of ecological studies and biodiversity conservation. Given the rarity of many of these species and their sensitivity to human disturbance, field monitoring and documentation are of significant scientific importance for understanding their distribution dynamics, identifying nesting sites, and analyzing their breeding and feeding behaviours. The Barbary Falcon (*Falco pelegrinoides*) is a breeding species in North Africa, with its range extending from the Canary Islands eastwards to the deserts of Central Asia. This species is primarily sedentary, although some vagrant individuals may be observed far from their breeding areas (Corso 2001; Ferguson-Lees and Christie 2001; White et al. 2013).

Some authors have treated the Barbary Falcon as a subspecies of the Peregrine Falcon (*F. p. pelegrinoides*) (Helbig et al. 1994; del Hoyo et al. 1994; Wink and

Seibold 1996). Others, however, consider it a distinct species, further divided into two subspecies: *F. pelegrinoides pelegrinoides* and *F. p. babylonicus* (Vaurie 1961; Clark and Shirihai 1995; Ferguson-Lees and Christie 2001). This taxonomic divergence is primarily explained by marked morphological differences, particularly in size and plumage patterning (Vaurie 1961; Clark and Shirihai 1995; Forsman 1999). We follow the latter view and consider it a full species.

Across its entire range, the majority of scientific studies have been conducted in the Canary Islands (Hernández et al. 1991; Peter and Kestenholtz 1998; Gainzarain 2006; Rodríguez et al. 2011, 2018, 2019; Siverio et al. 2011), where the species has been the subject of detailed research focusing on its biology, ecology, biogeography, and various aspects of its reproduction.

In Algeria, this species has, to date, not been the subject of any dedicated studies. Available data are limited to incidental records in inventories and general surveys of raptors across various regions of the country (Bouhra-

oua et al. 2008; Ababsa et al. 2013; Boumaaza 2017; Bouchahdane 2021; Kherchouche et al. 2021; Youcefi and Marouf 2022), with no targeted analyses conducted.

The present study provides the first data on the reproductive biology of the Barbary Falcon in Algeria. It offers a detailed analysis of the entire breeding cycle, from pair formation to the fledging of juveniles, incorporating associated behavioural and demographic parameters

MATERIALS AND METHODS

Study area

The present study was carried out in Djebel Amour, located in Laghouat province in central-southern Algeria. The Djebel Amour mountain chain located in the semi-arid bioclimatic stage extends between latitudes 33°45'N and 33°24'N and longitudes 1°30'E and 2°24'E, from El Bayadh province in the southwest to the south-western limit of the mountains of Ouled Nail in Djelfa province (Koudri 2013). The massif spans a vast mountainous area of the Saharan Atlas, encompassing several peaks reaching approximately 2.008 m (Djebel Ksel), and forms a topographic barrier between the Sahara Desert to the south and the high plains to the north (Figure 1).

Falcon (*Falco pelegrinoides*) in the Djebel Amour Mountains, located in Laghouat province in central Algeria. It also displays the administrative boundaries of neighbouring provinces, namely Tiaret, Djelfa, El Bayadh, and Ghardaïa, to provide geographical context for the study area. The nesting sites recorded during the present study are located in two municipalities: El

Ghicha and Tadjrouna. The points shown on the map represent the nest locations identified during field surveys. An inset map shows the position of the study area at the national scale within Algeria.

Nest searching and tracking methods

The search for and location of the nests was the result of collaboration between the forestry administration and the team from the falconers' association of Laghouat province. The nests were located through careful monitoring of the nesting pair's behaviour during their movements. Once the nests were located, they were visited daily to determine the exact date on which the first egg was laid. Afterwards, monitoring continued at a reduced frequency (every 3 to 4 days) during the laying period, followed by weekly visits from the start of incubation until the chicks fledged. The monitoring method adopted consists of a direct observation of a raptor in its environment, with the naked eye or using a telescope and binoculars. A total of three nests were identified, the first two located in the north, in the mountains of Jebel El Amour in El Ghicha, and the third nest located southwest of Laghouat, at Kef El-Melh station in Tadjrouna. The distances of the nests from dwellings, roads, agricultural areas, and bodies of water were measured as the crow flies using Google Earth Pro. The egg dimensions were measured using a digital calliper (150 mm/6"). The egg weight was measured using a digital pocket scale (200 g × 0.01 g).

To avoid disturbing the breeding pairs, the height and orientation of the nest were measured after the breeding season. The characteristics of the nests are presented in Table 1.

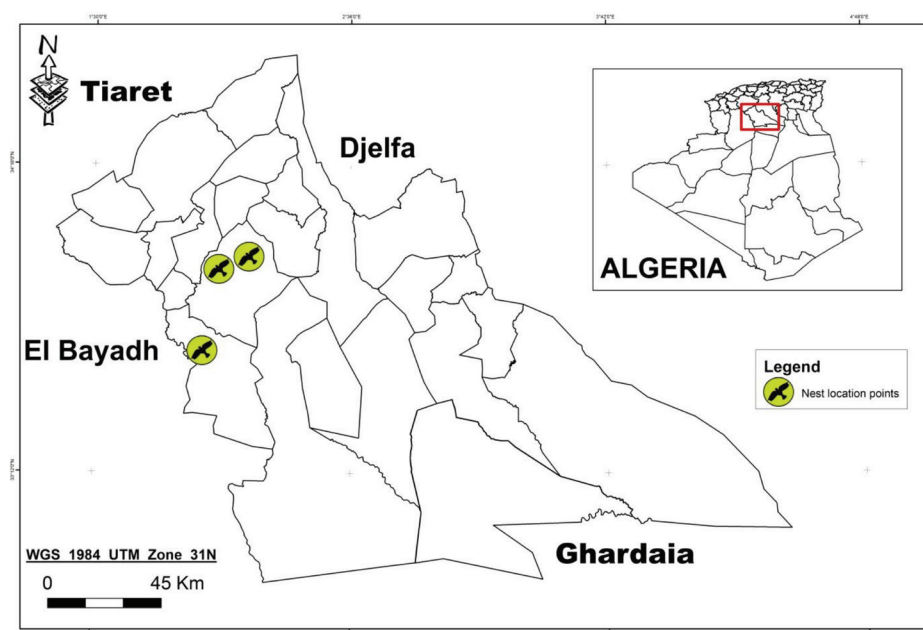


Figure 1. Map showing the location of the study area and the nesting sites of the Barbary Falcon.

Table 1. Nests characteristics in the Djbel El Amour region.

Nest	Long	Lat	Elevation	Nest expo	Nest height	Site type	Distance from:			
							Dwellings	Road	Agricultural zone	Water body
1	33°38'1.36"N	1°55'46.47"E	1227	North East	109 m	Mountainous area	14 km	515 m	13 km	728 m
2	33°56'53.11"N	2°3'23.26"E	1300	North	16 m	Wooded thicket	6.5 km	2.7 km	1.9 km	323 m
3	33°57'40.42"N	2°8'31.80"E	1255	South East	39 m	Wooded thicket	1.35 km	1.3 km	810 m	96 m

Table 2. Reproductive parameters and measurements of Barbary Falcon eggs.

Nest	Absolute fecundity	Start laying date	End laying date	Eggs measurements			Real fecundity	Fledging date
				Length (mm)	Width (mm)	Weight (g)		
1	4 eggs	20/02	26/02	51.4 ± 1.4	41.9 ± 0.9	45.2 ± 2.5	4 (100%)	19/05
2	4 eggs	22/02	28/02	52.0 ± 1.6	42.3 ± 1.0	46.4 ± 2.8	4 (100%)	20/05
3	3 eggs	28/02	03/03	50.5 ± 1.6	41.6 ± 0.9	43.9 ± 2.1	3 (100%)	23/05

Date and period of egg-laying

Incubation is assumed to commence with the laying of the last egg, while the nesting period is considered to begin with the hatching of the first egg (Nur et al. 2004). Laying dates are retrospectively calculated based on estimates of chick age and the average duration of egg incubation (Telailia 2014). The laying period is defined as the interval between the laying of the first egg by the earliest pair and that of the first egg by the latest pair (Auer et al. 2007).

RESULTS

The first pair of Barbary Falcon was observed at the nesting site during the first week of February 2021, three weeks before egg-laying. The Barbary Falcon pairs remained together throughout the entire breeding season. Prior to the laying period, the male Barbary Falcon mates with his female 1 to 3 times a day on average, and also throughout the entire laying period they mate with a daily frequency of 4–6 matings, particularly in the days immediately preceding egg-laying. The start of the breeding season falls in the last third of February.

The nests were situated in cliffs at an average height of 54.6 m. Some of these nests were lined, whilst others were not. Two nests containing four eggs and one nest containing three eggs were subjected to morphometric measurements. The results are shown in Table 2.

The first egg was laid on 20 February 2021. The eggs are of pinkish-cream colour with reddish-brown to purplish speckles (Figure 2a, b). Eggs were laid at intervals of 36 hours approximately. The incubation period lasted 32 days. Once egg-laying was complete, the female incubated the eggs from the first to the sixteenth or seventeenth day (Figure 2c), whilst the male hunted and

brought her food. Ten to fourteen days before hatching, the male and female took turns incubating the eggs.

Of all the Barbary Falcon nests monitored, all the eggs (11 across the 3 nests) hatched successfully, with the first egg hatching on 24 March 2021; the chicks remained in the eggs for 2 to 3 days after hatching. As soon as the chicks, which are altricial (Figure 2d), emerged, the pair took turns hunting and bringing food to the chicks. Whilst the female hunted, the male guarded the nest (Figure 2e).

At the start of the feeding period, the parents feed the chicks mainly on small birds (sparrows, rock pigeons, wood pigeons, Eurasian collared doves, European greenfinches, European siskins, canaries, etc.). As the chicks grow, other prey are added to their diet, such as reptiles (Biberon's agama and whip-tailed agama) and rodents (*Meriones shawii* and sand rat).

The Barbary Falcon chicks fledged 56 to 60 days after hatching, between 19 and 23 May 2021 (Table 2, Figure 2 f, g, h). During the two weeks prior to fledging, the parents brought live prey and taught the chicks to kill it in order to practise hunting. The post-fledging dependency period for the chicks lasted one month on average. Finally, from 20 to 25 June, the young dispersed, whilst the parents undertook a local migration to the south of the province (Hassi R'mel, Hassi Dellaa, etc.). The average prey provision rate and the dimensions of the nesting cavities were not taken into account so as not to disturb the pairs.

DISCUSSION

Although the Barbary Falcon appears to be present across much of Algeria, particularly in the Saharan Atlas, the information published to date is limited to a few



Figure 2. Barbary Falcon reproduction: (a: nest with 4 eggs, b: nest with 3 eggs, c: female during brooding, d: Barbary Falcon chicks, e: male during nest guarding, f: nest with 3 young falcons, g: nest with 4 young falcons, h: pre-flight training of Barbary Falcon nestlings).

records from certain nationwide surveys (Bouhraoua et al. 2008; Ababsa et al. 2013; Boumaaza 2017; Bouchahdane 2021; Kherchouche et al. 2021; Youcefi and Marouf 2022). It is a sedentary species in the Laghouat region; the female lays 3 to 4 eggs (Isenmann and Moali 2000). From monitoring by observers it was found that the incubation period of this species lasts about a month; it nests on steep cliffs in mountainous regions with a semi-arid climate, in areas sheltered from disturbances and that are very difficult to reach. However, most of the time the female is affected and stripped of her chicks. It is a target bird because of its special hunting properties (Zerouala, pers. obs.). According to Algerian law, it is classified as a protected species according to Executive Decree No 12-235 of 3 Rajab 1433 corresponding to 24 May 2012, fixing the list of non-domestic animal species protected.

In our study area, all the nests were located in cliff cavities, with one of the nesting cavities being higher than the other two (109 m compared with 16 m and 39 m). The average height of the nests is around 55 m above ground level, which is close to the average height chosen by the Barbary Falcon in Iran (61 m) (Shafaeipour et al. 2016), although it is lower than that of the cavities occupied by the same bird of prey on the islands of El Hierro (225 m), Tenerife (142 m) and La Palma (63 m) in the Canary Islands (Rodríguez and Siverio 2006; Rodríguez et al. 2007; Rodríguez and Siverio 2019).

In our study, the nests were located about 1.5 km from the road on average, with the nearest nest situated 0.515 km away; this is almost the same distance as that found in Iran, which averaged 1.48 km (ranging from 0.48 to 2.4 km) (Shafaeipour et al. 2016). The nearest settlement to the nests was 1.35 km away; the nests were located 7.5 km from the settlements on average, whereas in Iran, according to Shafaeipour et al. (2016), the nests were located 2.24 km (ranging from 1.25 to 4.18 km) from villages. The three nests faced different directions (north, north-east and south-east), whereas in Iran, of four nests, two faced south and the other two south-west (Shafaeipour et al. 2016). On El Hierro, nesting cavities had two orientations (north and north-east) with an orientation index of 1.8 (Rodríguez and Siverio 2006). On the Canary Islands, the main nest orientations are north, north-west, south-east and east (Rodríguez and Siverio 2019). Furthermore, the average distance between the nests and bodies of water was 0.382 km, whilst the distance from agricultural land varied approximately between 1 and 13 km.

Egg-laying began between 20 and 28 February and ended between 26 February and 3 March. This is an early period compared to other nesting areas of this falcon. In Iran, egg-laying takes place from 1 to 9 March (Shafaeipour et al. 2016). The same applies to La Palma,

where it begins in March (Rodríguez and Siverio 2019). In northern Mauritania, the Barbary Falcon breeds around February–March (Brouwer and Muillie 2000). In Egypt, nesting has been consistently observed in March and April (Goodman and Meininger 1989). On the Arabian Peninsula, it breeds in early April, coinciding with spring migration, which allows it to feed its young on migratory passerines (Platt 1988).

The incubation period we recorded was 32 days for all nests. In Iran, the incubation period lasted between 28 and 30 days (Shafaeipour et al. 2016). For the Lesser Kestrel of Lanzarote, the estimated period was quite short, ranging from 27 to 29 days (Delgado et al. 1999).

Although the sample size was small ($n = 3$ broods), the total absolute fertility was 11 eggs, and the average absolute fertility was 3.66 eggs. The effective fertility rate (number of fledglings) was 100%, with 11 chicks successfully fledging. However, it is likely that climatic stability, low density, the characteristics of nesting cavities, food availability, the quality of individuals, and the absence of potential predators may explain some of these results.

In Iran, out of 7 broods, the average absolute fertility was 4 eggs, whereas the average actual fertility was 3.43 fledglings (Shafaeipour et al. 2016). According to Delgado et al. (1999), the average absolute fertility on the Canary Islands (Lanzarote) was the same as ours (3.6 eggs), whilst the actual fertility was much lower (1.76 fledglings) across 26 broods on the island of Tenerife (Rodríguez et al. 2007). On the same island, Siverio et al. (2011) reported a rate of 1.92 fledglings, and 2.24 fledglings on Teno. Whereas on La Palma, 1.9 fledglings were recorded (Rodríguez and Siverio 2019). In Morocco, 2.3 fledglings per pair were recorded (Thévenot et al. 2003); the pair at Djebel Mhasseur regularly raised only a single chick. Due to food rationing, the strongest chick eliminates all its siblings who appear to starve to death. The rate of infertile eggs can reach 2 out of every 3 in the clutch (Brosset 1967). The chicks fledged at 56 to 60 days of age, whereas in Iran the period is shorter (41 to 42 days) (Shafaeipour et al. 2016).

Fertility in birds of prey is linked to several factors, such as population density (Carrete et al. 2006; Bretagnolle et al. 2008), the number of rainy days (Zuberogoitia et al. 2013; Anctil et al. 2014), prey size (López-López et al. 2009; Brosset 1967) and the quality of individuals, particularly males (measured by the number of prey items brought to the nest) (Zabala and Zuberogoitia 2014; Shafaeipour 2014). The Barbary Falcon is heavily dependent on migratory birds for feeding. It breeds during the Palaearctic-African spring migration (Brosset 1967; Hogg 1983; Platt 1988; Brouwer and Muillie 2000).

CONCLUSION

Given a high nesting success rate, as evidenced by clutch size, hatching rate and the number of fledglings that successfully left the nest, it can be concluded that the Barbary Falcon is certainly expanding into new areas across the Atlas Mountains. However, our results remain limited due to small sample sizes used in the study; they should therefore be interpreted with caution. Nevertheless, this study provides the first precise data on the nesting of this raptor in one of its main ranges and breeding areas. These data will support future conservation decisions, habitat management, and continuous population monitoring. Despite the efforts made in this study to provide as much information as possible on the nesting habits of the Barbary Falcon in the Saharan Atlas, our bioecological understanding of the species remains incomplete. It would therefore be desirable for future studies to be more in-depth and to focus on several aspects, notably population density, habitat selection and preference, diet composition; population age structure and individual quality, in order to better understand the current status of populations and predict their future dynamics.

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