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On the breeding biology of Alexander's kestrel (*Falco tinnunculus alexandri*) on Maio Island, Cabo Verde

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RESUMO

O conhecimento da biologia reprodutiva das aves de rapina é essencial para o desenvolvimento de medidas de conservação eficazes que melhorem as taxas de sobrevivência. Este estudo fornece os primeiros dados de monitorização da subespécie endémica *Falco tinnunculus alexandri* durante a época de reprodução na ilha do Maio, Cabo Verde. Foram recolhidos dados durante o período de incubação, incluindo o número de ovos, dados biométricos, pesos, dieta e comportamento dos juvenis. Os resultados mostraram que menos de metades dos juvenis sobrevivem em cada ninho. A competição e o canibalismo entre os juvenis foram confirmados nesta subespécie. Além disso, a análise da dieta revelou que o francelho-de-Alexander preda espécies endémicas, como o pardal-da-terra *Passer iagoensis* e lagartixa espinal do Maio *Chioninia spinalis maioensis*. Estas descobertas são de extrema importância para aumentar o conhecimento da sua biologia reprodutora, informação importante para delineamento de medidas de conservação desta subespécie em Cabo Verde.

Palavras-chave: Aves de rapina, biometria, dieta, nidificação, sucesso reprodutor

ABSTRACT

Knowledge on the reproductive biology of birds of prey is essential to develop effective conservation measures and increase their survival rates. This study provides the first monitoring data available of the endemic subspecies *Falco tinnunculus alexandri* during the breeding season on the island of Maio, Cabo Verde. Data were collected during the incubation period, including the number of eggs, biometric data, weights, diet and behaviour of juveniles. The results show less than half of juveniles survived per nest. Competition and cannibalism between offspring were observed in this subspecies. Additionally, the diet analysis revealed that Alexander's kestrel preys on endemic species, such as the Cabo Verde sparrow *Passer iagoensis* and Maio skink *Chioninia spinalis maioensis*. These findings are extremely important for increasing knowledge of its reproductive biology, which is important information for outlining conservation measures for this subspecies in Cabo Verde

Keywords: Birds of prey, biometrics, diet, nesting, breeding success

INTRODUCTION

The Common kestrel (*Falco tinnunculus*) is a widely distributed bird of prey, occurring across the Palearctic, Afrotropical and Oriental regions (Cramp 1980, White *et al*. 1994, Sale 2016). The species inhabits open habitats with abundant food resources (Butet *et al*. 2010), feeding on small mammals, birds, reptiles and insects (Aparicio 2000, Kübler *et al*. 2005, Riegert *et al.* 2007, Żmihorski & Rejt 2007). The prey spectrum can vary seasonally and geographically (Khaleghizadeh & Javidkar 2006). Nesting occurs in various settings, including tree cavities (Shrubb 1993), cliffs, rocks (Anushiravani & Sepehri Roshan 2017), buildings (Charter *et al*. 2007), and artificial nest boxes (Costantini *et al*. 2010, Boileau & Bretagnolle 2014).

Reproductive traits of island birds often differ from those of mainland birds (Isenmann 1982, Kuusela 1983, Thibault *et al*. 1992). These include smaller clutch sizes, later laying dates and adaptations to insular conditions (Cody 1966, Wiggins *et al*. 1998, Carillo & González-Dávila 2005). Factors influencing these differences include habitat variation (Grant 1965), climatic conditions (Blondel 1985), genetic factors (Frankham 1997), island size and isolation (Wiggins *et al*. 1998), as well as predator and parasite pressures (Williamson 1981, Møller 1997). In Cabo Verde, two subspecies of the Common kestrel are recognized: *Falco tinnunculus neglectus* on the northwestern islands and *Falco tinnunculus alexandri* on the southeastern islands (Hazevoet 1995, Hille *et al*. 2003). On Maio Island, the breeding subspecies is *Falco tinnunculus alexandri* (Ontiveros, 2005, Veiga *et al*. 2022). Despite its wide distribution across habitats on the island, there is limited information about its biology (Hazevoet 1995). Previous studies in the archipelago have focused on taxonomy, distribution, breeding phenology, and diet (Bourne 1955, Naurois & Bonnaffoux 1969, Naurois 1987, Hazevoet 1995, Ontiveros 2005), but detailed reproductive data remain unavailable (Hazevoet 1995). This study aims to improve the knowledge of the breeding biology of Alexander's kestrel on Maio Island. We investigated breeding phenology, clutch size, reproductive success, juvenile biometrics, and diet composition for future research to build on and inform conservation strategies for this endemic subspecies.

MATERIAL AND METHODS

The study was conducted on Maio Island, Cabo Verde (15º16'12.0'N, 23º12'0.0'W; Fig. 1) from October to February during the breeding seasons of 2022, 2023 and 2024. Nine Alexander's kestrel nests (three per year) were monitored. The nests were located on low sedimentary rock cliffs and palm trees *Atlantic phoenix* (Fig. 2A, B, C). Incubation time (n = 9) was monitored using infrared sensor cameras (SOLOGNAC-BG500) installed in nests from the laying of the last egg until hatching.

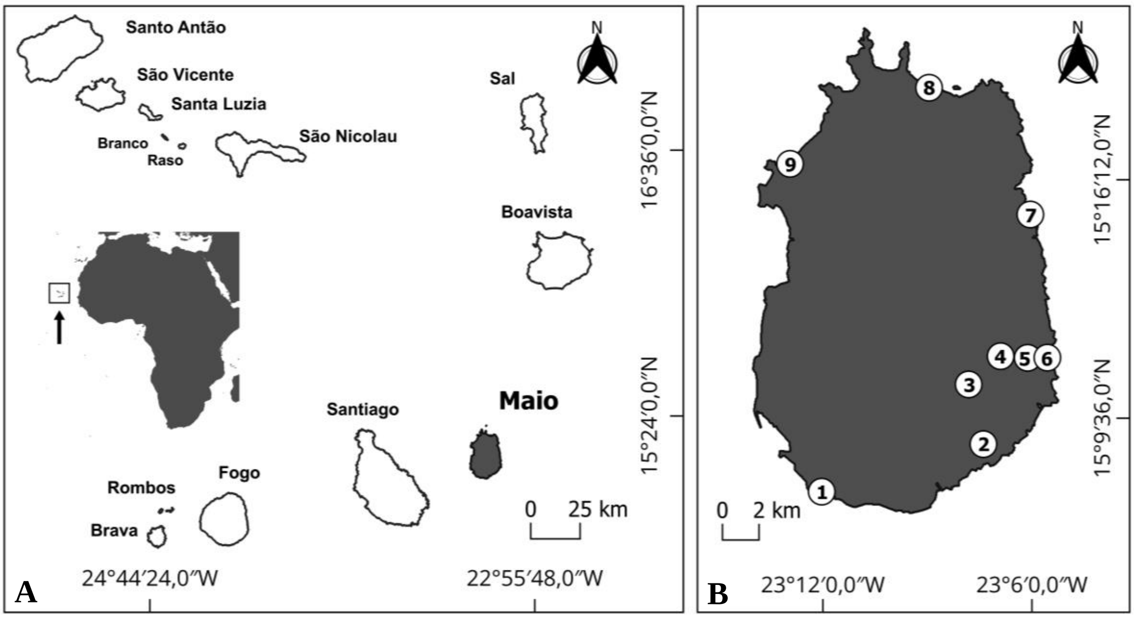

Fig. 1. Study area: **A**) Cabo Verde Archipelago and its location off the west coast of Africa, (black arrow) with Maio Island shaded, **B**) Location of monitored nests on Maio Island (numbered white circles).

In the most accessible nests (n= 4), eggs (n= 19) were counted and measured (length and maximum width) using a portable calliper (BM-RS/150 mm, accuracy ± 0.05 mm) and weighed using the digital scale (Smart Weigh Digital Pro Pocket Scale TOP2kg, accuracy ± 0.1). Egg volume (V), was calculated using the formula of Douglas (1990): $V= Kv*L* W^2$ (Kv, egg volume coefficient, L, egg length and W, egg width). After hatching, juveniles (n= 5) in two nests were weighed and measured weekly (culmen length, head-to-culmen length, wing length, wingspan length, tarsus length and weight).

In each nest (n= 9), hatching success (percentage of eggs that hatched) and survival success (number of fledglings from each nest) were calculated. After hatching, food remains (n= 48) found in the nine nests were collected, identified and counted weekly. The proportion of occurrence for each prey group was calculated, based on the quotient between the number of individuals of a given prey category and the total number of individuals of all prey categories x100. The behaviour of juveniles was monitored by cameras with infrared sensors installed in the nests from hatching until the juveniles left the nest. All statistical analyses were performed using R software version 4.2.2 (R Core Team 2022).

Fig. 1. Photos of the different stages of *Falco tinnunculus alexandri* in the nest: **A)** Breeding female of the Alexander's kestrel in front of the nest in a palm tree. **B**) Eggs incubated by a pair of kestrels in cavities of sedimentary rocks. **C, D**) Nestlings in the first few days after hatching. **E)** Nestlings on their second week of age. **F)** Two juveniles ready to leave the nest.

RESULTS

In the nine Alexander's kestrel pairs monitored, incubation lasted for 22.6 ± 1.5 days on average (Fig. 2B). In nine nests, the average number of eggs per clutch was 4.5 ± 0.8 eggs (Fig. 2B). Nineteen eggs from four most accessible nests had an average weight of 18.0 ± 1.4 g, an average length of 38.0 ± 1.1 mm and an average width of 30.6 ± 0.8 mm and an average volume of 18.3 ± 1.0 cm^3. The biometrics of five juveniles from two nests measured and weighted in the first week after hatching were as follows: average culmen length was 8.8 ± 0.8 mm, the average head-culmen length was 33.6 ± 2.0 mm, the average wing length was 29.0 ± 4.8 mm, the average wingspan was 138 ± 23.1 mm, the average tarsus length was 25.1 ± 4.4 mm and the average weight was 52.4 ± 23.9 g (Fig. 3). The biometrics of five juveniles measured and weighted in the last week before leaving the nest (fifth week) were as follows: average culmen length was 12.8 ± 0.4 mm, the average head-culmen length was 45.3 ± 0.5 mm, the average wing length was 179.8 ± 1.8 mm, the average wingspan was 560.3 ± 5.9 mm, the average tarsus length was 48.6 ± 0.3 mm and the average weight was 182.7 ± 11.0 g (Fig. 3). The average hatching success of eggs from nine nests was 69.4 ± 32.3% (Fig. 2C, D) and juvenile survival was 35.2 ± 25.3 % (Fig. 2E, F).

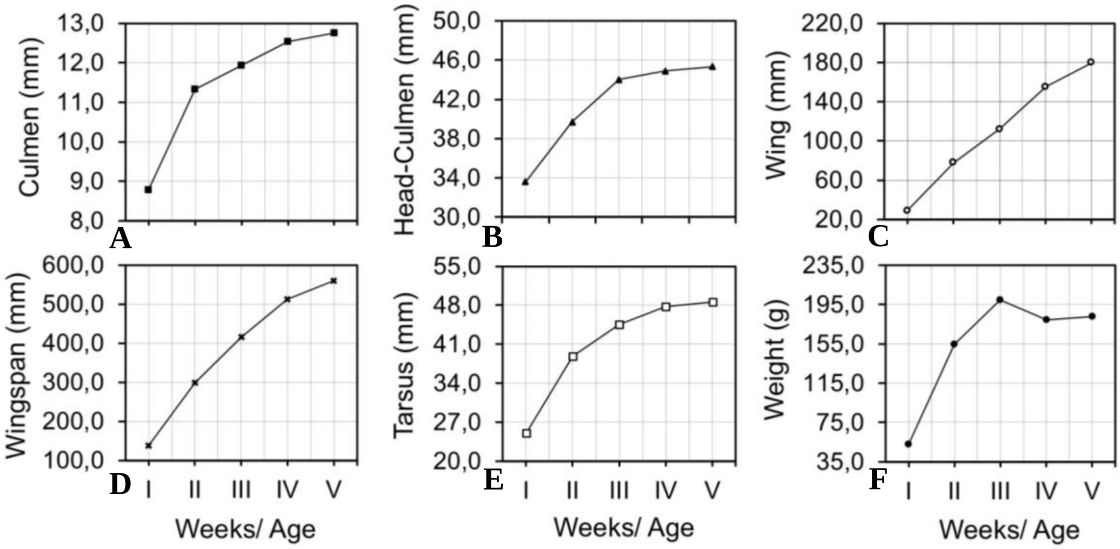

Fig. 3. Graphs representing mean weekly growth of 5 juvenile kestrels: **A**) Culmen length, **B**) head-to-culmen length, **C**) wing length, **D**) wingspan length, **E**) tarsus length, and **F**) weight.

Of the 46 food items collected from the nests, eight different prey species, including insects, reptiles, birds and mammals were identified (Table 1). In two of the nests, the dominant juvenile was observed pushing its siblings out of the nest. Cannibalism was recorded in one of the nests, with two siblings feeding on the third (dead) one. Juveniles left the nest during the fifth week after hatching in all the nests.

Table 1. Prey species found in nests and respective percentage of occurrence. The proportion (% SOP) of species occurrence in prey remains as well as the number of prey remaining in the nests (Nº. Prey) for a total of 46 prey are provided. Species that are endemic to Cabo Verde are marked with an asterisk (*****)

Class	Species/ Subspecies	Common name	% SPO	Nº prey
Insects	*Oedaleus senegalensis*	Senegalese grasshopper	6.5	3
Reptiles	*Chioninia spinalis maioensis*	Maio skink *****	21.7	10
Birds	*Ammomanes cinctura*	Bar-tailed lark	10.9	5
	Coturnix coturnix	Common quail	2.2	1
	Eremopterix nigriceps	Black-crowned sparrow-lark	8.7	4
	Gallus gallus domesticus	Domestic chicken	6.5	3
	Passer iagoensis	Cabo Verde sparrow *****	34.8	16
Mammals	*Mus musculus*	House mouse	8.7	4
All			100.0	46

DISCUSSION

The results indicate that Alexander's kestrel exhibits reproductive traits similar to other common kestrel populations, such as clutch sizes of 3–6 eggs (Massemin *et al*. 2002, Valkama *et al*. 2002, Anushiravani & Roshan 2017, Kabeer *et al*. 2021) and egg volumes ranging between 16.10 and 25.30 cm^3 (Valkama *et al*. 2002). However, incubation periods were shorter (22.6 days vs. 27–31 days documented elsewhere; Anushiravani & Roshan 2017, Charter *et al*. 2008, Valkama *et al*. 2002, Kabeer *et al*. 2021) and average hatching success was lower (69.4% vs. 84.4–87.5%; Anushiravani & Roshan 2017, Kabeer *et al*. 2021). Reproductive characteristics of birds of prey can vary between islands and regions (Lack 1968, Cody 1971, Isenmann 1982). It is assumed that insularity may affect the reproductive biology of raptors in different ways (Carillo & González-Dávila 2005), and these discrepancies may reflect adaptations to particular environmental conditions of Maio Island, including food availability, climate, and predator pressure (Hille *et al*. 2003). The mortality of juvenile Alexander's kestrels in the nests on Maio Island is above the ranges recorded in other populations (64.8% vs. 55–59%; Wiehn *et al*. 2000). One of the causes of mortality observed in some nests was intra-clutch competition and cannibalism, which are two known and described phenomena in falconiforms (Bonabeau *et al*. 1998, Redondo *et al*. 2019, Romano *et al*. 2022). Observations of intra-clutch competition and cannibalism suggest adaptive strategies to maximize survival under unpredictable feeding conditions (Bonabeau *et al*. 1998, Markham & Watts 2007, Hadjikyriakou & Kirschel 2016). The diet composition of Alexander's kestrel on Maio was similar to that in other regions, including small mammals, birds, reptiles, and insects (Aparicio 2000, Kübler *et al*. 2005, Riegert *et al*. 2007, Żmihorski & Rejt 2007). On Maio Island, Alexander's kestrel, preys mainly on endemic species (56.5%), which are abundant and have a conservation status of low concern on the Red List, such as *Passer iagoensis* (BirdLife International 2024) and *Chioninia spinalis maioensis* (Vasconcelos 2013), that should not raise concern about this predation. In addition, it also captures chickens (6.5%), which may be a source of conflict with local human communities (Stahl *et al*. 2002, Avery & Cummings 2004, Zuluaga *et al*. 2016).

It is hoped that these findings will encourage further ecological studies of this taxon to provide additional information supporting the improvement of its habitat conditions on the island.

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