

Notes and Comments

Frugivory and primary seed dispersal of *Elaeis guineensis* by birds of prey

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In tropical forests, frugivorous animals play a fundamental role in maintaining biodiversity by feeding on fruits, transporting seeds to sites far from the mother plant, and releasing them in favorable conditions for germination and establishment of seedlings, thus reducing predation rates, pathogen infection, and intraspecific competition for resources, besides promoting gene flow within and between populations (Fleming and Kress, 2013). However, the efficiency of this process is directly related to the feeding behavior of the frugivorous animals and their mobility after feeding (Jordano and Schupp, 2000).

With high displacement capacity and diversity of frugivorous species, birds comprise one of the most important groups for seed dispersal in Neotropical forests (Jordano et al., 2006; Quintero et al., 2020). Ornithochory (seed dispersal by birds) has been widely studied and the knowledge generated highlights the importance of species that have the ability to ingest and transport large fruits and seeds, such as representatives of the families Ramphastidae (Toucans and Aracaris), Cotingidae (Bellbirds and Cotingas), Cracidae (Chachalacas, Guans, and Curassows), and Trogonidae (Trogons) (Silva and Tabarelli, 2000).

The Neotropical region is also home to a great diversity of birds of prey. This is a group well adapted to predation whose species have strong, sharp claws, curved and pointed beaks, great agility and high visual acuity (Hoyo et al., 1992; Sick, 1997). With these characteristics, these birds are not seen as potential dispersal agents and, therefore, they are neglected as to their importance for plant reproduction. However, they can act in the secondary dispersal of seeds, through a complex interaction known as diploendozoochory (double endozoochory). This interaction allows the dispersal of seeds that were first ingested by the prey of these birds (Nogales et al., 2007; Pérez-Méndez and Rodríguez, 2018).

Some studies highlight the importance of diploendozoochory for the maintenance of impoverished dispersal assemblages typical of island ecosystems (Nogales et al., 2007; López-Darias and Nogales, 2016). However, the direct consumption of fruits and the role of these birds in the primary dispersal of seeds are still little known and mainly registered through anecdotal records

(Galletti and Guimarães, 2004; Young and Bell, 2010; Pérez-Méndez and Rodríguez, 2018; Paula et al., 2021). Given the above, the present study aimed to analyze the feeding behavior and primary dispersal of seeds of African oil palm *Elaeis guineensis* Jacq. by birds of prey through direct visual observations carried out in the municipality of Olinda, Pernambuco, Brazil, in addition to consultations to the collection of photos on the Wikiaves website, and a bibliographical review.

The observations were carried every month between 2016 and 2021 in the municipality of Olinda (08°0'34" S; 34°51'19" W), Pernambuco, Northeastern Brazil. During this period, were performed direct visual observation sessions on non-consecutive days (minimum of 20 min and maximum of 60 min) in two individuals of African oil palm (about 12 m tall), between 5:00 am and 5:00 pm, totaling 42 hours of observations. I used 8 x 32 binoculars, a camera, and a GPS device to estimate seed dispersal distance. We considered a visit the period in which the birds arrived and remained feeding until leaving the plant. I also consulted the collection of photos on the Wikiaves website, "The Encyclopedia of Birds of Brazil" (<https://www.wikiaves.com.br>), where photos showing birds feeding on fruits were considered as records of frugivory, and photos showing birds flying with the fruit in their beaks or feeding on a fruit outside of the mother plant as a record of dispersal. I reviewed the literature using ISI Web of Science, Google Scholar (keywords: African oil palm, birds of prey, frugivory, seed dispersal), and different books on natural history of birds (Hoyo et al., 1992; Sick, 1997) and reviews (Pérez-Méndez and Rodríguez, 2018).

Elaeis guineensis is an African palm (Arecaceae) native from humid tropical region, whose fruits and seeds are widely used to produce palm kernel oil. The palm was introduced in southeast Asia, and tropical South and Central America (Hartley, 1988). Fruit production is continuous throughout the year. The fruits have an oblong shape, are arranged in large clusters, have an orange coloration, oily mesocarp, and a single seed. To obtain morphometric data (length and width) of the diaspores, 50 ripe fruits were randomly collected (25 from each of two different

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tree). I used a digital caliper with 0.1 mm precision for measurements.

The fruits had an average length of 38.1 ± 2.8 mm and width of 25.8 ± 1.9 mm. The seeds had an average length of 26.5 ± 2.9 mm and width of 18.8 ± 2.0 mm. During the observations, I recorded 71 visits made by four species of raptors, distributed in three orders, which consumed a total of 127 fruits (Table 1). During foraging, the birds

used their beaks to remove ripe fruits directly from the bunches. Then they fed on the pulp while on the tree. For this, they held the fruit with one of their talons and removed the mesocarp with their beak, soon after discarding the seed (Figure 1).

Caracara plancus (Miller, 1777), *Milvago chimachima* (Vieillot, 1816) and *Cathartes aura* (Linnaeus, 1758) in addition to consuming the fruits on the tree, also carried

Table 1. Frugivory and dispersal of African oil palm seeds by birds of prey in the municipality of Olinda, Pernambuco, Brazil.

Taxon	Total number of visits	Total of fruits consumed (mean)	Seed dispersal events
CATHARTIFORMES			
Cathartidae*			
<i>Cathartes aura</i>	19	45 (2,36)	3
ACCIPITRIFORMES			
Accipitridae			
<i>Rupornis magnirostris</i>	3	4 (1,33)	-
FALCONIFORMES			
Falconidae			
<i>Caracara plancus</i>	47	75 (2,58)	18
<i>Milvago chimachima</i>	2	3 (1,5)	1

*Scavengers.



Figure 1. Birds of prey feeding on African oil palm fruits in the municipality of Olinda, Pernambuco, Brazil. A and B – *Caracara plancus*; C – *Cathartes aura*; and D – *Rupornis magnirostris*. Photos: Leonardo B. da Silva.

out the primary dispersal of seeds by flying with the fruits in their beaks to other locations (22 records) (Table 1). I was able to monitor and measure the dispersal distance in 15 events performed by *C. plancus* (Figure 2). We recorded fruit consumption and/or seed dispersal of African oil palm in other seven species in the literature review and the Wikiaves website, where around 100.000 photos were analyzed (Table 2).

African oil palm fruits fall within the “megafauna syndrome”, that is, large fruits that need large frugivores to disperse their seeds (Guimarães Júnior et al., 2008). Nowadays, in the Neotropical region there is a great incompatibility between the size of these fruits/seeds and the gape width, and ingestion capacity of extant animals, a pattern aggravated by habitat fragmentation and selective hunting of large frugivorous birds (Silva and Tabarelli, 2000; Dirzo et al., 2014) However, birds of prey can be efficient in dispersing large diaspores, precisely because they have a large beak width and because they have the ability to move over long distances (Galletti and Guimarães, 2004; Pérez-Méndez and Rodríguez, 2018; Paula et al., 2021).

In addition to the ability to ingest and transport the fruits in the beak, these birds can also play an important role in seed germination because during the removal of the pulp,

the curved and pointed beak can cause scarification in the endocarp, allowing greater exposure to moisture and gas exchange, condition that can increase the speed and rate of germination (Lorenzi et al., 2010; Neves et al., 2013). In the

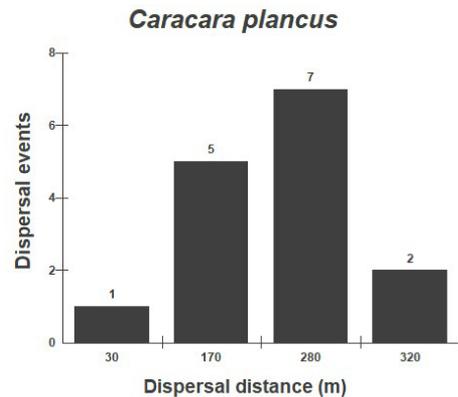


Figure 2. Distribution of seed dispersal distances of the African oil palm, by the *Caracara plancus* in the municipality of Olinda, state of Pernambuco, Brazil.

Table 2. Records of frugivory and dispersal of African oil palm seeds by birds of prey.

Taxon	Photographic records on the Wikiaves website (n)		Reference	
	Frugivory	Seed dispersal	Frugivory	Seed dispersal
CATHARTIFORMES				
Cathartidae				
<i>Coragyps atratus</i>	4	-	-	-
<i>Cathartes aura</i>	9	-	Pérez-Méndez and Rodríguez, 2018; This work	This work
<i>Cathartes burrovianus</i>	3	-	-	-
ACCIPITRIFORMES				
Accipitridae				
<i>Elanoides forficatus</i>	-	-	Olmos et al., 2006	-
<i>Rupornis magnirostris</i>	-	-	This work	-
<i>Gypohierax angolensis</i> *	-	-	Pérez-Méndez and Rodríguez, 2018	Carneiro et al., 2017
<i>Polyboroides typus</i> *	-	-	Pérez-Méndez and Rodríguez, 2018	-
FALCONIFORMES				
Falconidae				
<i>Caracara plancus</i>	2	-	This work	This work
<i>Daptrius ater</i>	1	1	-	-
<i>Milvago chimachima</i>	5	4	Olmos et al., 2006; This work	This work
<i>Falco ardosiaecus</i> *	-	-	Pérez-Méndez and Rodríguez, 2018	-

*Species from the African continent.

case of palm trees, these scarifications are very important, as the woody endocarp represents a physical barrier to seed germination (Lorenzi et al., 2010). In fact, seeds with scarifications and some African oil palm seedlings were observed in the places where the birds discarded the seeds after consuming the pulp, indicating the germination of the processed seeds.

In the scenario of intense deforestation and defaunation in which tropical forests are embedded, complex ecological interactions such as the dispersal of large diaspores are among the first to disappear (Silva and Tabarelli, 2000; Dirzo et al., 2014). In this context, birds of prey can act efficiently in a niche that is highly threatened by the absence of large frugivorous birds (Silva and Tabarelli, 2000; Galletti and Guimarães, 2004). Many species in this group, such as those recorded in this study, are resilient and common in several Neotropical ecosystems (Sick, 1997; Sazima, 2007), and seem to prefer large fruits with pulp rich in lipids (Galletti and Guimarães, 2004). These characteristics associated with large displacement capacity may be important for the ecological restoration process (Jordano et al., 2006).

However, the fact that these birds are known mainly for their carnivorous diet leads to little attention on the part of researchers as to their role in the seed dispersal. In the Neotropical region, the few studies conducted so far describe anecdotal records, mainly involving Falconidae species (Galletti and Guimarães, 2004; Pérez-Méndez and Rodríguez, 2018; Paula et al., 2021). This knowledge can be expanded with the help of “citizen science”, through observation and photographic recording of birds in nature. Birdwatching is an activity of great socio-environmental interaction, and digital photographic sharing platforms represent the main means of disseminating this activity. Through the images, researchers can access information about the diet of different groups (Wikiaves, 2021). Therefore, a closer look by researchers and amateur ornithologists at the frugivorous diet of these birds and their feeding behavior can help us to better understand their role in primary seed dispersal.

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