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Infanticide and cannibalism by parents of the Golden Eagle *(Aquila chrysaetos)*: a case report in Sicily

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Abstract Parental infanticide followed by cannibalism remains a relatively understudied phenomenon, particularly among birds of prey. This behaviour, where parents kill their own offspring, is often considered an adaptive strategy for brood reduction in response to limited food availability during chick-rearing. In this brief report, we describe a case of siblicide followed by parental infanticide and cannibalism observed in a Golden Eagle *(Aquila chrysaetos)* nest, monitored via webcam in Nebrodi Regional Park, Sicily (Italy). Using video footage from the entire breeding attempt, we documented the sequence of events in detail, including prey deliveries, feeding frequency for each chick, and the number and intensity of aggressive interactions from hatching to the chicks' deaths. Our analysis suggests that the primary driver of this behavior was a severe shortage of food, likely linked to adverse weather conditions during the nesting period. We conclude that the infanticide and subsequent cannibalism were a result of insufficient prey provisioning caused by unfavorable climatic factors.

Keywords: aggression, Golden Eagle, infanticide, cannibalism, Sicily

Összefoglalás Az utódok szülők általi halála és az azt követő kannibalizmus viszonylag kevéssé vizsgált jelenség, különösen a ragadozó madarak körében. Ezt a viselkedést gyakran a fiókanevelés során a korlátozott táplálék elérhetőségére válaszul alkalmazott adaptív stratégiának tekintik a fészekalj csökkentésére. Ebben a rövid közleményben a testvérgyilkosság, majd a szülői utódgyilkosság és kannibalizmus egy esetét írjuk le, amelyet a szicíliai Nebrodi Regionális Parkban (Olaszország) webkamerával megfigyelt szirti sas *(Aquila chrysaetos)* fészkében figyeltünk meg. A teljes költési kísérletről készült videofelvételek segítségével részletesen dokumentáltuk az eseménysorozatot, beleértve a zsákmányszállítást, az egyes fiókák etetési gyakoriságát, valamint az agresszív interakciók számát és intenzitását a kikeléstől a fiókák haláláig. Elemzésünk szerint a viselkedés elsődleges mozgatórugója a táplálék súlyos hiánya volt, amely valószínűleg a fészkelési időszak alatti kedvezőtlen időjárási körülményekkel függött össze. Arra a következtetésre jutottunk, hogy az utódgyilkosság és az azt követő kannibalizmus a kedvezőtlen éghajlati tényezők okozta elégtelen zsákmányellátás következménye volt.

Kulcsszavak: agresszió, szirti sas, utódok szülők általi halála, kannibalizmus, Szicília

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Introduction

In the animal kingdom, there are extreme and rare cases where parents would not only kill their own offspring but also feed on them. This phenomenon, parental infanticide followed by cannibalism is a relatively underexplored phenomenon, especially in birds of prey (see e.g. Markham & Watts 2007, Bose 2022).

There are instead several records reporting infanticide and cannibalism perpetrated by non-parental individuals. Intraspecific predation of nestlings by intruding birds is one case of infanticide followed by cannibalism and documented among several raptor species. (e.g. Rosenfield & Papp 1988, Bortolotti *et al.* 1991, Webster *et al.* 1999). For example, in Bald Eagle *(Haliaeetus leucocephalus)*, a subadult male was recorded to kill two nestlings after the death of their father and when their mother was out of the nest (Markham & Watts 2007).

Cainism or siblicide, reported in several large birds of prey, such as the Bearded Vulture (*Gypaetus barbatus*, Thaler & Pechlaner 1980), and some eagle species around the world (Meyburg 1974a, b, Brown *et al.* 1977, Stinson 1979, Edwards & Collopy 1983, Simmons 1988, 1989, Gargett 1990, Meyburg *et al.* 2008), occurs when the oldest sibling kills the youngest one. In Golden Eagle, cainism (together with cannibalism) is commonly observed in the population of Western Carpathian (Group for Conservation and Research on the Golden Eagle in Slovakia unpubl. data). This phenomenon is characterized by escalating conflicts between siblings resulting in a siblicide event where the youngest sibling dies from lethal attacks due to the continuous physical aggression of the older one (Ellis 1979, Newton 1979, Collopy 1980, Edwards & Collopy 1983, Sakaguchi & Chiba 1988, Bortolotti *et al.* 1991, Haraszthy *et al.* 1996, Watson 2010).

A recent study (Redondo *et al*. 2019) highlighted that intense sibling aggression among raptors, particularly in the Accipitridae, is typically associated with species characterized by large adult body size, small clutch sizes, low provisioning rates, and slow development. The results of this research indicate that the intensity of aggression tends to be higher in species with lower parental investment (small clutch sizes and low provisioning rates), whereas the effects of adult body mass, nestling period duration, and food abundance appear to be minimal.

Parental cannibalism, thus parents consuming their own offspring, is a phenomenon known for several animal species, including birds (Polis & Myers 1985, Kevles 1986, Klug & Bonsall 2007, Mociño-Deloya *et al.* 2009) and, among them, several species of diurnal raptors (Ingram 1959, Solaro & Sarasola 2012, Lewis 2017), such as some species of the genus Aquila (Real 1991, Garcìa-Dios 2003, Gonzàlez *et al.* 2006, Korňan & Macek 2011, Caro 2014). The probability of a parental cannibalism event depends on the environment and the offspring or parental conditions during a reproductive event (Bose 2022). In any case, in most occurrences, parents consume chicks that had just died for starvation or other causes, thus they do not perform the infanticide *per se* (Bortolotti *et al.* 1991, Garcìa-Dios 2003, Markham & Watts 2007).

Parental infanticide in birds is rare (e.g. Aguilera 1990, Urrutia & Drummond 1990, Tortosa & Redonto 1992, Zieliński 2002) and, in particular, among raptors (Wiemeyer 1981, Bortolotti *et al.* 1991, Webster *et al.* 1999). Parental attacks resulting in the dead of their

own offspring (Hrdy 1979, Mock 1984, Franke *et al.* 2013) is often reported as a strategy needed for brood reduction due to unfavorable trophic availabilities during chick raising (Hrdy 1979, Newton 1979, St. Clair *et al.* 1995). Indeed, in most occurrences, parents use the killed chick to feed the remaining ones but not themselves.

In a few words, most of our records pertain either cannibalism or infanticide, while there is virtually no evidence showing infanticide followed by cannibalism perpetrated by the parents. To our knowledge, the only exception occurred in a Golden Eagle nest monitored by a camera system. There, the parent female killed the youngest nestling who served as a food item both for herself and the survived chick (Korňan & Macek 2011).

Here, we report a case of siblicide first, followed by parental infanticide and cannibalism in a Golden Eagle nest in the Nebrodi Regional Park (Sicily, Italy). As we video-recorded all events, we were able to quantify and detail not only the interactions between siblings and between them and their parents but also the prey items brought to the nest. This allowed us to suggest some hypotheses to pursuit in future studies about the causes of this phenomenon and the scarcity of its records.

Method

In 2023, we monitored the breeding attempt of a pair of Golden Eagle nesting at the Nebrodi Regional Park (Sicily, Italy) with the use of two webcams (Led 2.0-megapixel Starlight WDR 120 dB day-and-night and Ultra 265/H.265/H264/MJPEG) placed at approximately 10 m from the nest. The images captured by the webcams during the whole day (including the night) were transmitted to the park headquarters and there were video-recorded.

All prey delivered to the nest during each observation period were identified to species level and assigned to a size class (e.g. fox – young or adult). Prey biomass was calculated using estimates of size class for each carcass delivered and species-specific body weights (Steenhof 1983) by searching specialist literature for each taxon.

We compared the number of morsels provided to both chicks using Monte Carlo t test (9999 permutations) performed by Past 4.03 software.

Results

We analyzed 144 hours of video recordings covering from 27 May to 2 June. The first egg hatched on 27 May at 15:20 (CET) followed by the second egg approximately 13 h later, at 06:15 on 28 May. On 31 May, the youngest chick died and at 18:21, when the female started to rip from the chick carcass a few morsels. These were used first for its own consumption (she is clearly visible swallowing the morsels) and then, at 18:22, for feeding the older chick. On the morning of 2 June the oldest chick began to react weakly to the female's stimuli. Indeed, contrarily to the previous six days, it barely moved when, at 14:44, the female started offering the chick a prey morsel by touching its beak with hers. At 16:08 the female started inflicting several strikes upon the chick, which was still alive as clearly moving.

Table 1. Prey species, and their biomass, brought to the nest as recorded during the nesting attempt of a pair of Golden Eagle at the Nebrodi Regional Park (Sicily, Italy) in 2023

1. táblázat A fészekbe hozott zsákmányfajok és biomasszájuk a Nebrodi Regionális Parkban (Szicília, Olaszország) 2023-ban egy szirti sas pár fészkelési kísérlete során rögzítettek szerint

Days (MM/DD)	Prey	Biomass (g)	Biomass (g/day)
05/27	*Hierophis viridiflavus*	300	300
05/28	*Erinaceus europaeus* (young)	500	500
05/29	Lacertidae sp.	35	35
05/30	No prey	0	0
05/31	*Vulpes vulpes* (young)	1300	1300
06/01	No prey	0	0
06/02	Ophidae sp.	200	250
06/02	*Hierophis viridiflavus*	300	

Table 2. Number of times the chicks were fed and sibling attacked as recorded during the nesting attempt of a pair of Golden Eagle at the Nebrodi Regional Park (Sicily, Italy) in 2023

2. táblázat A fiókák etetésének és a testvérek megtámadásának száma a Nebrodi Regionális Parkban (Szicília, Olaszország) 2023-ban egy szirti sas pár fészkelési kísérlete során rögzített adatok szerint

Date (MM/DD)	No. of prey morsels provisioned to				No. of prey morsel/day	No. of attacks
	first-born chick		second-born chick			
	Mean	± SD	Mean	± SD		
05/28	10.20	3.70	3.20	3.42	5	15
05/29	12.90	4.43	4.00	4.00	10	8
05/30	7.33	7.28	7.67	5.24	6	14
05/31	12.67	10.69	0	0	5	
06/01	12.00	5.00	0	0	4	

When the chick died the female started eating it. Over the period analyzed, a total of six prey items were brought to the nest, with an average biomass of 439.17±448.11 (mean±SD) g per prey. Prey delivery occurred on four out of six days (i.e. no prey was brought to the nest for two days), bringing the daily biomass to 340.71±462.08 g/day *(Table 1)*.

The female fed the chicks 30 times in total (21 until the death of the younger chick and nine afterward, *Table 2*) spending 439±229 seconds per feeding activity. The number of morsels provided to both chicks were significantly different (t_{23}= 4.071, Monte Carlo p= 0.0003), with the older chick receiving, on average, a higher number of morsels per feeding (11.2±6.6) than the younger (4.43±4.47). From the second day after hatching, we counted 37 attacks between chicks *(Table 2)* as they involved the older chick pecking the other and making physical contact between its beak and different body parts of its younger sibling. Out of the total, 45.9% (n=17) of the attacks occurred during prey delivery. Attacks became shorter and shorter with time as they lasted 149.3±92.0 sec (n=15), 82.5±71.6 sec (n=8) and 41.6±37.6 sec (n=14) on the 2nd, 3rd and 4th day after hatching, respectively.

Discussion

This scarcity of observations of infanticide followed by cannibalism in bird nests may be due, at least partially, to the relatively rare frequency of such events and the difficulty of continuously monitoring nest activities, particularly on the first days after hatching as chicks are frequently covered by their parents (Markham & Watts 2007).

Here, we reported not only a detailed case of infanticide followed by cannibalism but also an estimate of the most probable drive to such events, thus scarcity of food provisioning. A similar case of infanticide and cannibalism in Golden Eagle was reported by Korňan and Macek (2011). The authors offered two possible explanations for the observed phenomenon. The first, proposed as an example of a parent female with an aberrant behavior, was considered very unlikely. In fact, during the long-term monitoring (1995–2010) at this nest, the researchers reported this phenomenon only in 2004 despite the fact that the parent female did not change (i.e. she had very specific plumage features). Likewise, we discarded such an explanation for our observations. We have been monitoring this nest since 2006 but observed infanticide and cannibalism only in 2023. Although the adult birds were not individually tagged, we believe that the same female has been breeding in the nest for the past several years, due to specific plumage characteristics well documented by the video footages.

With the second explanation, the authors proposed that the infanticide was caused by low food supply, which suggests that both chicks and parent female suffered an important feeding stress. This hypothesis was consistent with a lower prey biomass brought to the nest before infanticide (i.e. 994±1325 g/day, Korňan & Macek 2011) than the one delivered in typical nests (i.e. 1251±426.5 g/day, Collopy 1984). This last hypothesis is the most consistent with our observations. We recorded a daily food intake (340.714±462.083 g) well below than the one reported by nests both without (1251±426.5 g/day, Collopy 1984) and with (994±1325 g/day, Korňan and Macek (2011) occurrence of infanticide and cannibalism. Specifically, before the infanticide and during the first two weeks after hatching, we recorded a biomass of 994±1325 g/day and 452±313 g/day, respectively, again much lower than those reported by Collopy (1984) for the same periods (1258 and 776 g/day, respectively).

Such a low prey supply in our study might be due to the inclement weather (from the first day hatching to the first and to the second infanticide, data available at https://www.ilmeteo.it/portale/archivio-meteo/Messina/2023/Maggio) occurred during the nesting period, with heavy cloudiness, rain and wind, plausibly preventing male hunting activities. The month of May 2023 (the wettest since 1921) was effectively characterized by persistent atmospheric instability over the Sicilian region, with abundant and anomalous precipitations (http://www.sias.regione.sicilia.it/, Sicilian agro-meteorological information service). Poor weather conditions may both affect negatively the offspring survival and prompt parents to cannibalize their young, as shown in the Peregrine Falcon *(Falco peregrinus)* (Franke *et al.* 2013).

We finally ruled out that infanticide and cannibalism might be caused by an unusual nesting period because this breeding attempt had a similar timing than the others observed for this pair in the past years.

The present study, in conclusion, allows us to describe another rare case of infanticide and cannibalism in Golden Eagle, highlighting the importance of monitoring through webcams to

record events and behaviors that are impossible to record through normal monitoring activities. This would allow us to reveal whether such behaviors are more common than what has been recorded so far.

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