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A first detailed description of building a new nest and new data on the courtship behaviour of golden eagle

Prvý podrobný opis stavby nového hniezda a nové údaje o imponovaní orla skalného

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Abstract: The nest building and courtship behaviours of the golden eagle are poorly represented in the scientific literature. The paper reports on the first detailed description of building a new nest by a pair of golden eagles. Reciprocal pendulum flight by the pair as part of a pre-breeding courtship display is described for the first time. The "mock attack" between the members of the pair is confirmed to serve the courtship function.

Abstrakt: Poznatky o stavbe hniezda a imponovanie orla skalného sú vo vedeckej literatúre málo zastúpené. Príspevok informuje o prvom podrobnom opise stavby nového hniezda párom orlov skalných. Prvýkrát je opísaný vzájomný kyvadlový let páru ako súčasť predhniezdneho dvorenia. Potvrdzuje sa, že "predstieraný útok" medzi členmi páru plní funkciu dvorenia.

Key words: nest building, display, reciprocal pendulum flight, mock attack

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Introduction

The nest-building behaviour in birds is still considered understudied (Breen et al. 2016). Among diurnal birds of prey for a long time, it used to be little studied and poorly represented in the scientific literature (Meyburg 1967, Newton 1979), but in recent decades a few detailed studies were published (Gargett 1990, Fernandez 1992, Margalida & Bertran 2000, Xirouchakis & Mylonas 2007, Martínez et al. 2022).

The golden eagle (*Aquila chrysaetos* Linnaeus, 1758) has a Holarctic distribution and occupies the role of apex predator in different ecosystems (Watson 2010). Even though it is the fifth most studied raptor species (Buechley et al. 2019), only a few publications reported on aspects of its nest-building behavior (Camenzind 1968, Fernandez & Leoz 1986, Aoyama et al. 1988, Ellis et al. 2009, McIntyre & Paulson 2015), while Ellis & Schmitt (2017) provided a general description.

For building nests, golden eagles use branches and sticks and line them with grass, moss and lichen (Watson 2010). This behaviour can occur at any time of the year, but it is most frequent from autumn through late winter (Watson 1997) with most buildings in weeks just prior to laying (Gordon 1955) and usually done between 10 a.m. and 1:30 p.m. (Dixon 1937). In the Central Balkans, the breeding season starts in the second half of January, when birds perform aerial displays, reconstruction of the nest and mating (Grubač 1988, Michev et al. 1989). Nest building of already existing nests varies greatly between pairs, with some almost doubling the size of nests before egg-laying, while others are barely changed (Camenzind 1968). Before egg-laying and throughout the nestling period, the pairs add "greenery" to the nest (Meyburg 1969, Bergo 1987, Watson & Rae 2019), consisting of fresh tree branches with green leaves. Usually, the eagles remove these branches when the leaves begin to wilt and replace

them with fresh ones (Watson & Rae 2019). In Japan, one pair of golden eagles studied by continuous video monitoring added 109 items of nesting material during 95 days before egg-laying, with both birds contributing roughly equally (Aoyama et al. 1988). During a 46-year-long survey, Kochert & Steenhof (2012) reported 14% of pairs never built a new nest and stated that it remains unclear why some pairs build and use newly constructed nests and others do not. Regarding the building of a completely new nest by golden eagles, to my knowledge, only Fernandez & Leoz (1986) provide some brief, but very general information for the construction of a newly built tree nest.

The nest-building of birds has been associated with courtship and pair formation (Soler 1998). However, the courtship behaviour of even well-studied raptors has been under-reported (Ellis, 1992). Watson (1997) stated 25 years ago that the courtship in golden eagle is poorly documented in the literature and it remains so until today. Golden eagles usually make very conspicuous and long dives to their nests and make undulating displays (sequences of dives followed by ascents) that serve mostly territorial signalling and defence functions (Harmata 1982, Collopy & Edwards 1989). Variation of the undulating display is the rarely seen "pendulum flight", also described as the "figure of eight" (Crane & Nellist 1999), but the eagles frequently perform flights that are intermediate between the two (Bergo 1987). They are often associated with the presence of intruder within the nesting territory (Bergo 1987). Usually, males initiate undulating flights but they may be followed by the female (Negro & Galvan 2018). The aerial manoeuvres may give individuals the opportunity to gauge skills (Watson 1997) and reveal individual qualities (Wiacek 2004). In terms of proportion of the total flight time of the male and female, these displays account for respectively 0.4% and 0.1% (Collopy & Edwards 1989). However, at the beginning of the breeding season, undulating flights may take a huge amount of the daily flight time, e.g., one single territorial male in Ethiopia, displayed 51% of the time during 115 minutes of observation (Clouet et al. 1999). The undulation displays may serve also a "nuptial" function, such as pair bonding (Brown & Amadon 1968, Bahat 1989 in Watson 2010, Crane & Nellist 1999). However, recent observations by Reid et al. (2019) could neither confirm nor reject this. "Mock attacks" within the pair are rarely observed (Grubač 1988, Ivanovskii 2010, Crane & Nellist 1999) and Bergo (1987) recorded only nine such cases (seven of them between newly establishing pairs) and suggested that they serve courtship function during pair formation.

The paper presents first quantified details on the building of a completely new nest and provides additional details on the poorly understood courtship behaviour of the golden eagle.

Material and methods

Studied area

The observations covered the period of nest-building before the onset of egg-laying. The work was conducted for 16 days during 31.01 – 4.03.1999 in "Sinite Kamani" Nature Park, Eastern Balkan range, Sliven province, Bulgaria (approximate coordinates N42.71° E26.36°). The area is a low mountain, with many scattered cliffs along the south-facing slopes of the mountain, and an oak-dominated forest with few openings. Dominant tree species were sessile oak (*Quercus petraea*), hungarian oak (*Quercus frainetto*), turkey oak (*Quercus cerris*) and montpellier maple (*Acer monspessulanum*). Observations were made with a binocular (10x50) and telescope (20 – 60 x 60) by one to three people, from a viewpoint located in a very small opening in the forest, next to a bigger meadow trespassed by a rarely used tourist path. It was distanced at 400 m from a cliff nest of a pair of adult golden eagles, and situated 130 m lower in elevation. The pair of eagles never showed any signs of distress due to the presence of observers. The cliff in the area of the nest was about 25 m high and the nesting niche was not known to have been used anytime in the past, so it was built by the birds for the first time. For the whole time, a total of 31 h 16 min were spent in observations, 45.7% in the morning and 54.3% in the afternoon. Detailed notes on the behaviour were recorded by minute using the method "ad libitum" (Altmann 1974). All cases of nest building were recorded, with the type of material brought to the nest and the location from where it was collected. Unusual behaviours were described in detail. When the birds perched, it was possible to distinguish them, with the smaller male being significantly darker on the breast than the female. Special attention was devoted to behaviours concerning nest building, courtship, territorial displays and interspecific relationships with other raptors. The observed behaviour of the birds is described according to Bergo (1987), Watson (2010) and Ellis & Schmitt (2017).

Results

Nest building

From the 16 field days with observations, golden eagles were recorded in 11, from which in 10 days both members of the pair. The nest was constructed for a minimum

period of 25 days and nest-building activity was observed in six of them, peaking roughly a month before egg-laying (7 March) – at the end of January and beginning of February. Peak activity was around midday and more than 95% of cases of nest-building occurred between 10 a.m. and 1:30 p.m. In 85% of the cases of nest building, the weather was sunny with temperatures above 4°C. The birds were within sight during 50.2% (15 h 42 m) of the total time, for a daily average of 85 min (8 – 198 min). In total, 65 instances of carrying nesting material into the nest were recorded (2 – 31 per day) with either tree branches (92%), or dry grass (8%). Of the 36 cases, when the sex of the bird was identified, the male brought material in 17 cases, and the female in 19. Branches were collected from the ground (mostly fallen ones) and trees by breaking them off, respectively in 77 and 23% of cases (n = 59), when the place of gathering was identified. The plant material was collected mostly at 200–300 meters from the nest (range 50–600 m). The eagles carried the plant material mostly in the feet, but in 11% of cases in their beak, mostly smaller branches, once a big branch about 70 cm long, and once dry grass. Branches varied in length (10 – 120 cm), but most often, they were about 40–50 cm long. In the 16 days before egg-laying, the studied pair added branches of common ivy (*Hedera helix*). Nine days before egg-laying and on the last day when nest building was observed, the eagles brought on four occasions only dry grass to the nest, used for the lining of the cup, while no branches were added.

While collecting branches from trees, the eagles most often landed within the crowns of larger trees and broke off a single branch with their beak. While flapping during landing and taking off, the birds frequently hit many mostly smaller branches. Occasionally, after perching inside the crown, while searching for a suitable branch, the eagles moved horizontally up to 2 – 3 m along the perch or flapped from one bigger branch to another. In more than 90% of cases, the eagles flew in a mostly straight line from the place of gathering of the material to the nest by using a diving or steep descent flight before landing. On four occasions in flight, an eagle unintentionally dropped the branch and in two cases dove after it either as a play or in an attempt to try to catch it in midair, but without success.

Courtship: reciprocal "pendulum flight", mock attack and diving flight to enter the nest

On 7 February (a month before egg laying), a two-year-old bird passing through the nesting area was chased away by the male after three deep stoops very close to it and followed with escorting flight (Bildstein & Collopy 1985), while it was retreating. Very soon, the female appeared from the opposite direction. The pair met and circled together, and then both of them initiated undulating displays. At a moment when the birds were a few hundred meters apart, they simultaneously initiated "pendulum flight" (diagram in Bergo 1987), stooping towards each other, passing with great speed just a few meters one from another, then after ascending and reaching the highest position, turned and dove back, passing very close for the second time.

On 27 February, the male and female circled together and once demonstrated a mock attack, with the male attacking from above, diving for several meters, the female turning half over and presenting talons, after which the birds perched on cliffs in front of the nest immediately followed by copulation. For the whole survey period, six copulations were recorded from 5 to 28 February, with three of them on the 27 and 28, i.e. eight and nine days before the onset of incubation. All copulations were on cliffs, distanced 10 to 600 m from the nest, with three of them at about 200 m.

When the eagles were approaching from a higher position to land in the nest, they used downward closed-wing-stoop or delta-wing-stoop (Ellis & Schmitt 2017) always in cases, when it was energetically justifiable. This was most evident on a day (5 February), when they collected nesting material in 13 cases from an area at higher elevation than the nest and in 12 cases landed in the nest after a steep diving flight. On the 20 of February, the eagles brought material in eight cases, with three of them from a lower position than the nest and then they did not use stooping flight but stooped on the remaining occasions when they were coming from a higher position. Unusual cases included: 31 January – the male carried dry grass in its bill towards the nest, stopped and hovered for 2 sec. at about 20 meters before the nest, then dived in, but lost the grass and tried to catch it unsuccessfully. On the 5 of February – before landing with a branch, the male did a pirouette at 8–10 m above the nest, then landed; 20 of February – one came with a branch from more than 700 m, made two consecutive steep dives towards the nest, but did not land and went back towards the direction where it came from.

Discussion

The paper reports the first description of the building of a completely new nest by the golden eagle. Large raptors rarely build a completely new nest in the year in which they breed (Newton 1979), but the pair that was observed

managed to fledge one chick. The building of a new nest in the golden eagle, is a very rare event to observe, since nests may last for many decades and in exceptional cases after repeated reuse, persist for centuries (Ellis et al. 2009, Jenny et al. 2023). The nest that was built, had below-average size and a large part of it was in a quite narrow, cave-like niche, and only the nest rim was visible from the low observation point. For the 65 recorded cases of carrying nesting material by the birds, the total number may be at least twice higher. The observation showed that the majority of the time, the birds were building the nest in sunny warmer weather, which probably reflects the need for good flying conditions and minimization of the used energy. Similarly, sparrowhawks (*Accipiter nisus*) also did most of the nest building in spurts during warmer days (Newton 1986), while imperial eagles (*Aquila heliaca*) start nest building much earlier than normal in a year with a mild winter (Danko 2007).

The observed pair always collected nesting material within a kilometre radius, but occasionally golden eagles can carry it from 1.5 km (Grubač 1988). Especially in the winter, common ivy and fresh pine (*Pinus* sp.) branches are commonly used for the green lining of the nest in Bulgaria and other parts of Southern Europe, before any deciduous trees turn into leaf (Fernandez & Leoz 1986, Abuladze & Shergalin 2002, I. Angelov, pers. obs.). Such green material can be collected from up to three kilometres if it does not grow in the vicinity (Fernandez & Leoz 1986, Watson & Rae 2019) as it has an important function for signalling towards conspecifics (Canal et al. 2016) and repels ectoparasites (Wimberger 1984, Ontiveros et al. 2008). Previous studies in Bulgaria, involving nest inspection later in spring found scots pine (*Pinus sylvestris*), oaks (*Quercus* sp.), lilac (*Syringa vulgaris*), oriental hornbeam (*Carpinus orientalis*) and rarely oriental beech (*Fagus orientalis*) (Milchev & Georgieva 1992, Kouzmanov et al. 1996).

In nearly a quarter of the cases when branches were brought, they were torn off from trees, by the birds using their beaks. This behaviour probably reflects the need for incorporating stronger branches into the nest structure, since the dead branches on the ground are not as durable as the live ones (Newton 1986). Similarly, for a newly built nest on a tree, Fernandez & Leoz (1986) observed how the eagles tore and removed with their bills unwanted branches around the supporting foundation of the nest. While walking on the ground on the slopes, the birds looked clumsy, frequently balancing with wings.

The observation of a mock attack by the male, followed by copulation, supports the hypothesis first expressed by Bergo (1987), that the mock attacks between the members of the pair serve a courtship function (Grubač 1988, Crane & Nellist 1999). The same has been reported for the verreaux's eagle (*Aquila verreauxii*), especially for newly formed pairs, but it is "very occasionally seen" and the female "seldom does a half-roll" (diagram in Gargett 1990). Similarly, the reciprocal pendulum flight demonstrated by the pair was observed only once during the study and to my knowledge has never previously been described for the species. It followed the successful chasing away of an intruder by the male and most likely also serves a courtship function.

The observed instances of a pirouette and hovering just before entering the nest probably also serve courtship function, as may be the attempts to catch dropped nesting material in mid-air. In the two cases, when the eagles dropped the material before landing in the nest, the possibility for play behaviour could not be dismissed, since the attempts did not seem agile enough and the bird may have caught it if tried harder. For the black eagle, nesting material was sometimes dropped in the air when the bird tried to transfer it from the bill to the legs, or from one leg to the other, but the eagles never tried to retrieve it in mid-air, or from the ground (Gargett 1990). In the cases when the golden eagles were dropping material, such attempts for transfer of the material in flight were not noticed, but easily this may have been the reason. While doing such transfers, the eagles do a "cycling motion of the empty foot, or both feet" (Gargett 1990), which combined with the loosening grip of the carrying leg, may occasionally lead to the dropping of the material.

To the best of my knowledge, the paper is the only one, describing the building of a new nest of golden eagles, with details on the behaviour of the birds that enrich the understanding of the little-studied pre-laying period of the species. I am not aware of other publications describing the reciprocal pendulum flight of the golden eagle, thus it may be the first description of this behaviour. The observation of a mock attack by the male over the female of the pair, followed by copulation, confirms the hypothesis that it serves a courtship function (Bergo 1987).

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