Pre-incubation behaviour of a pair of Eurasian Eagle-owls (*Bubo bubo*) based on IR-video recordings at a nest site in Baden-Württemberg, Germany in 2014-2015

Comportamento pré-incubação de um casal de bufo-real (*Bubo bubo*) com base em gravações de vídeo de infravermelhos num ninho em Baden-Württemberg, Alemanha em 2014-2015

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ABSTRACT

Pre-incubation behaviours displayed by a pair of Eurasian Eagle-owls (*Bubo bubo*) at a nest site in Southern Germany were captured by infrared (IR) video camera. During courtship, the male exhibited behaviours to guide his mate to the nest site, to gain her acceptance of the site and to strengthen their pair bond in preparation for nesting. Prey presentation and transfer appeared to play a minor role in attracting the female to the nest site compared to male visual and acoustic signals. The duration of male visits varied from a few seconds to over 5 h (total of 47:44 h) but the average visit duration per night increased from 0:29 to 2:51 h and the visit frequency per night increased from 2.5 to 5.1 (N=139) over the pre-incubation period. The female's 29 visits (9:35 h total) also intensified over this period. Copulations were observed 3 weeks before egg laying. Later, the male frequently (n=14) laid down in the nest hollow in an incubation-like posture for >1 h periods. Likewise, in the 3 weeks before egg laying, the female frequently (n=10) spent considerable time (0:28 to 1:25 h) lying in the nest hollow in an incubation-like position. Web cameras have transmitted live footage from various owl nests in recent years but no scientific evaluation of recorded behaviour has been reported. This report provides the first analysis of pre-incubation behaviour of a pair of Eurasian Eagle-owls at their nest site under natural outdoor conditions.

Keywords: *Bubo bubo*, courtship, IR-video recording, nest site behaviour, pre-incubation

RESUMO

Os comportamentos exibidos por um casal de bufo-real (*Bubo bubo*) durante a pré-incubação num local de nidificação localizado no sul da Alemanha foram gravados com uma câmara de vídeo de infravermelhos (IR). Durante a corte, o macho exibiu comportamentos para conduzir a sua parceira ao local de nidificação, para induzir a aceitação do ninho por parte desta, e para reforçar a ligação do casal para preparar a reprodução. A apresentação e transferência de presas pareceu apresentar um papel menos importante na atração da fêmea ao local de nidificação, em comparação com os sinais visuais do macho e com sinais acústicos. A duração das visitas do macho variou entre alguns segundos até mais de 5 h (total de 47h44), mas a duração média das visitas por noite aumentou de 0h29 para 2h51, e a frequência das visitas por noite aumentou de 2,5 para 5,1 (N=139) ao longo do período de pré-incubação. As 29 visitas da fêmea (9h35 no total) também se intensificaram ao longo deste período. As cópulas foram observadas três semanas antes da postura. Mais tarde, o macho assumiu frequentemente (n=14) uma postura deitada, semelhante à de incubação, na cavidade do ninho por períodos superiores a 1 h. Da mesma forma, nas 3 semanas anteriores à postura, a fêmea passou frequentemente (n=10) tempo considerável (0h28 a 1h25) deitada na cavidade do ninho numa postura semelhante à de incubação. Nos últimos anos, têm sido transmitidas imagens em tempo real a partir de vários ninhos de rapinas noturnas através de câmaras online, sem que tenha sido reportada uma avaliação científica dos comportamentos registados. Este relatório apresenta uma primeira análise do comportamento pré-incubação de um casal de bufo-real no seu local de nidificação em condições naturais.

Palavras-chave: *Bubo bubo*, comportamento no ninho, corte, pré-incubação, vídeo de infra-vermelhos

Introduction

Analogue photo-trapping and video recording techniques have been employed in ecological studies for quite some time (Cutler & Swann 1999; Wratten 1994). More recently, digitalization, miniaturization, expanded functionality and reduced cost have stimulated further use of video technology in research (Ribic et al. 2012) and to stimulate public interest in bird watching and conservation. Cameras connected to the internet enable the public to live stream active nests from an increasing range of bird species, including owls. Expert commentary, supportive interpretation and additional information material has contributed to substantially enhance the educational value and impact beyond the visual experience afforded by the camera (see www.uhu.webcam.pixtura.de/tagebuch; www.ageulen.de; and other "livecam" websites). However, detailed and quantified peer-reviewed publications of bird activities and behaviour based on video recordings are rare for diurnal and nocturnal species alike (Bosch 2012, Bosch 2013, Nielsen et al. 2015; Harms 2017a, Harms 2017b; Kniprath 2018). Nocturnal species, such as owls, have been difficult to study (Zuberogoitia & Campos 1998) because of our limited abilities to observe their behaviour at night. Microelectronic devices such as radio-transmitters and infrared (IR) video technology have emerged as powerful new tools to overcome this limitation enabling the unobtrusive observation of nocturnal species at fixed locations such as nest sites.

Figure 1 - Cliff habitat containing an active Eurasian Eagle-owl (*Bubo bubo*) nest site in Baden-Württemberg, Germany in 2014-2015.

Figura 1 - Escarpa onde se localizava um ninho de bufo-real (*Bubo bubo*) ativo em 2015-2015, em Baden-Württemberg, Alemanha.

Figure 2 - Equipment employed to monitor a nesting pair of Eurasian Eagle-owls (*Bubo bubo*) in Baden-Württemberg, Germany in 2014-2015. Images are not to scale: (1) IR video camera, (2) wireless receiver, monitor and recording unit, (3) power supply.

Figura 2 - Equipamento usado para monitorar um casal de bufo-real (*Bubo bubo*) em Baden-Württemberg, Alemanha, em 2014-2015. As imagens não obedecem a uma escala: (1) câmara de vídeo de infravermelhos, (2) recetor sem fio, monitor e unidade de gravação, (3) fonte de alimentação.

For more than 2 decades, video-based research techniques at bird nest sites have been employed mainly in two areas: to study nest site predation (Bolton et al. 2007, Cutler & Swann 1999, Renfrew & Ribic 2003), and prey delivery by diurnal raptors (see references in Harms 2018a). While owl nest site webcams have been operational for several years (i.e., www.uhu.webcam.pixtura.de) there has been no published scientific evaluation of their behaviour during key stages of their reproductive cycle.

This paper presents a detailed analysis of behaviour of a pair of non-ringed (unbanded) Eurasian Eagle-owls (*Bubo bubo*) during the pre-incubation (courtship) period based on IR video recordings at a nest site in southern Germany in 2014-2015. A resident pair successfully nested in this location for several years in a row and was part of a small local regularly monitored population (Harms et al. 2015; Harms 2016; Harms & Lühl 2017, Harms 2018b).

This research is part of a long-term (since 1965) volunteer program (www.agw-bw.de) to monitor, ring (band), protect and conserve sympatric species inhabiting rock cliff habitats in the federal state of Baden-Württemberg including the Peregrine Falcon (*Falco peregrinus*), Eurasian Eagle-owl and Common Raven (*Corvus corax*). The program has been highly successful and instrumental in re-establishing and protecting the target species in the region from near-extinction to well above 200 occupied territories and breeding pairs in 2015 (Rau 2015).

Methods

Behaviours and activities of a pair of Eurasian Eagle-owls were recorded with a camera at their nest located 25 km West of Freiburg, Baden-Württemberg, Germany (Harms 2017a). The logistics and equipment used is the result of extensive trials as discussed by Harms (2015). To record a full reproductive season, the camera was installed November 2014 and was operated from December 2014 to early June 2015 when the fledglings permanently wandered off the nest. The nest was 20 m high up a calcareous rock cliff in a quarry and was sheltered from uphill vineyards by overhanging rocks and a row of shrubs and trees (*Robinia pseudoacacia*) (Fig. 1). The pole-mounted camera extended beyond the overhang and was positioned 3 m above and 7 m away from the nest. The recorded image took in the nest and the surrounding area (5 m wide and 3 m high).

Equipment (Fig. 2) was locally purchased for under 500 € and included a video camera (Visortech) with 24 infrared (IR) LEDs providing illumination at night to 10 m. The ¼-inch CMOS sensor produced low-quality colour pictures of 512x384 pixel resolution at 25 fps (frames per second) during the day and grey-scale pictures at 3-10 fps, depending on available light, at night. IR illumination was automatically switched on when ambient light was low. The low frame rate under IR-lighting caused fast-moving objects (i.e. owl in flight) to appear blurred on the pictures and made it difficult to observe fine details. The camera and recorder (see below) were powered by 12 V DC lithium-ion adjustable-output rechargeable notebook power banks (ReVolt) of 24,000 mAh capacity. A power cable extended between the camera and the remote battery and recorder locations. The video signal was transmitted wirelessly (2.4 GHz); for technical reasons acoustic signals were not recorded.

A remote receiver-monitor-recorder (Visortech) was used to receive, view and store video signals. Videos were automatically split into 15 min long files and stored on 32 GB SD-storage media using H.264 compression. A monitor was used to view the nest when exchanging batteries but was switched off during recording to extend battery life. The recorder and batteries were protected from the weather by a plastic bag. Due to their limited capacity it was necessary to exchange batteries and storage media once per day. The owls were not disturbed because

Table 1 - Summary information on the IR-video recordings of pre-incubation behaviour of a pair of Eurasian Eagle-owls (*Bubo bubo*) at a nest site in Baden-Württemberg, Germany in 2014-2015.
* time between sunset and sunrise, including dusk & dawn periods

Tabela 1 - Resumo das informações sobre as gravações de vídeo de infra-vermelhos referentes ao comportamento pré-incubação de um casal de bufo-real (*Bubo bubo*) num ninho localizado em Baden-Württemberg, Alemanha, em 2014-2015.

PERIOD	PRE-COURTING	COURTING	ALL PRE-INCUBATION
Date	Dec 8 - Dec 31	Jan 1 - Feb 21	
Calendar days	24	52	76
Recording days	11	37	48
Hours recorded [h:min]	189:40	641:20	831:00
- night time hours recorded* [h:min] (%)	170:47 (90.0)	536:40 (83.7)	707:27 (85.1)
- day time hours recorded [h:min] (%)	18:53 (10.0)	104:40 (16.3)	123:33 (14.9)
avg. recording time per recording day [h:min]	17:15	17:20	17:18

Table 2 - Behaviours of a male Eurasian Eagle-owl (*Bubo bubo*) at a nest site in Baden-Württemberg, Germany. Normal and *courting* behaviours are distinguished by font below, and were captured on IR-video recordings in the pre-courting period (December 2014).

Tabela 2 - Comportamentos de um macho de bufo-real (*Bubo bubo*) num ninho localizado em Baden-Württemberg, Alemanha. Os comportamentos normais (letra normal) e de corte (*em itálico*) foram registados em gravações de vídeo de infravermelhos no período de pré-corte (dezembro de 2014).

DATE	TIME	DURA-TION [MIN]	ACTIVITY
Dec 12	19:31 - 19:58	27	resting
Dec 14	04:57 - 05:04	7	*repeated excited tail lifting*; maintaining feathers, *calling*
Dec 16	07:36 - 07:45	9	resting, feeding, maintaining feathers, care of plumage
Dec 26	17:44 - 17:48	4	resting, leaves with prey remains taken from deposit
Dec 26	19:57 - 21:00	63	*excited tail lifting, calling*; resting
Dec 27	05:36 - 07:21	105	resting; maintaining feathers, care of plumage
Dec 31	04:50 - 07:29	159	resting, feeding, maintaining feathers; *calling* before take-off
Dec 31	07:35 - 07:44	9	arrives with prey in beak, walks about nest site, takes off
Summary	8 visits in 6 nights	383	mainly 'normal' behaviours; *few behaviours with courting connotation*

the recorder and batteries were placed above the cliff behind vegetation 15 m from the camera. Daily visits enabled a timely response to equipment failures.

Recorded videos were transferred to PC, replayed, and owl behaviour was written down in detail. Behaviours were later transposed into Excel for qualitative and quantitative analysis. As each video frame is time stamped, a precise, second-by-second sequence of behaviours can be described with respect to the duration and temporal intervals. Statistical methods followed McDonald (2014).

Adult Eurasian Eagle-owls are sexually size dimorphic (Marks et al. 1999), and the difference in relative size was used to distinguish the smaller male from the larger female when both owls were present. Previously published sex-specific Eurasian Eagle-owl behaviours (Marks et al. 1999) were also used to identify the male and the female, in addition to a distinct wing plumage pattern on the male. The male also had a habit of frequently closing its left eye.

The pre-incubation period was divided into a pre-courtship period and a courtship period. The pre-courtship period was defined by a concurrent Eurasian Eagle-owl survey program as being prior to 1 January 2015 (Harms 2016). Consequently, the courtship period is defined herein as 1 January to 22 February when the first egg was laid. However, it is acknowledged that this division was somewhat arbitrary in that the male was observed exhibiting a gradual increase in courtship behaviours over the pre-incubation period during visits to the nest site at night.

Results and discussion

Table 1 provides an overview of pre-incubation video recordings. The camera was operated at night intermittently prior to (11 of 24 nights) and during the courtship period (37 of 52 nights). Daytime recording was limited during these periods because the owls were not present at the nest site during the day (Table 1). The results presented and discussed include only data or information obtained from video recordings.

Pre-courtship period behaviour

The male visited the nest site a total of 6:23 h (3.7% of total recorded night hours) during eight visits on six nights during this period. The male exhibited some courtship behaviour during these visits such as excited tail lifting and calling (Table 2). On 26 and 31 December, I inferred that the female was perched nearby based on the male's behaviour. The male's visits appeared to be either short (4-9 min) or long (27-159 min), a pattern also observed during the courtship period. The female was not observed to visit the nest site during this period even though it is likely that she was aware of its presence, either because of the male's presence and/or if she was the same female that successfully reared chicks at this nest site in previous years.

Male courtship period behaviour

Courtship activities at the nest site increased in early January (Table 3). The number of the male's nest site visits per 10-day interval ranged from 15-26 for the first 40 days and then increased to 51 within the last 12 days before egg laying (Table 3). The average number of visits per night increased and the total time at the nest site also steadily increased; 60% of the time the male spent at the nest site was in the last 12 days before egg laying. This is also reflected in the gradual then large increase in the average time per night the male spent on the nest site (Table 3).

The duration and distribution pattern of the male's visits during courtship was highly variable (Table 4). More than half of all visits lasted for 5 min or less and such short visits occurred in all intervals of the courtship period and increased during the last time interval before egg laying. Visits exceeding 60 min also increased dramatically in the final

Table 3 - Quantitative aspects of nest site visitation by a male Eurasian Eagle-owl (*Bubo bubo*) as captured on IR-video recordings in the courting period (January 2015) in Baden-Württemberg, Germany.

Tabela 3 - Aspetos quantitativos das visitas ao ninho por um macho de bufo-real (*Bubo bubo*), conforme gravações de vídeo de infravermelhos no período de corte (janeiro de 2015) em Baden-Württemberg, Alemanha.

MALE ACTIVITY DURING COURTING	JAN 1 - 9	JAN 10 - 19	JAN 20 - 29	JAN 30 - FEB 9	FEB 10 - 21	TOTAL
Calendar days	10	10	10	10	12	52
Recording days	9	5	5	8	10	37
Nights with male presence	6	5	5	8	10	34
Number of visits	15	23	24	26	51	139
Avg. number of visits per night with presence	2.5	4.6	4.8	3.3	5.1	4.1
Duration of all visits [h:min:sec]	2:53:58	3:28:47	4:21:58	8:26:50	28:32:49	47:44:22
Cumulative duration of all visits [h:min:sec]	2:53:58	6:22:45	10:44:43	19:11:33	47:44:22	
Duration of all visits [%]	6.1	7.3	9.1	17.7	59.8	100
Cumulative duration of all visits [%]	6.1	13.4	22.5	40.2	100	
Avg. duration of visits per night with presence	0:29:00	0:41:45	0:52:24	1:03:21	2:51:17	1:24:15
Number of visits <5 min	8	18	15	11	29	81
Number of visits >60 min	1	1	2	4	6	14

Table 4 - Number and duration of nest site visits by a male Eurasian Eagle-owl (*Bubo bubo*) in Baden-Württemberg, Germany as captured on IR-video recordings in the courting period (January 2015).

Tabela 4 - Número e duração das visitas ao ninho por um macho de bufo-real (*Bubo bubo*) em Baden-Württemberg, Alemanha, conforme gravações de vídeo de infravermelhos no período de corte (janeiro de 2015).

Duration of visit [min]	<1	>1 - 5	>5 - 15	>15 - 30	>30 - 60	>60	cumulated
Number of visits	12	69	33	6	5	14	139
% of visits	8.6	49.6	23.7	4.33	3.6	10.1	100
% of visits, cumulated	8.6	58.3	82.0	86.3	89.9	100	
Duration of visits [h:min:sec]	0:06:06	2:59:48	4:37:35	2:12:01	3:38:20	34:10:32	47:44:22
% duration	0.2	6.3	9.7	4.6	7.6	71.6	100
% duration, cumulated	0.2	6.5	16.2	20.8	28.4	100	

courtship period interval (Table 3) resulting in a high proportion of the time the male was present at the nest just before egg laying (Table 3, Table 4). Over the entire courtship period more visits occurred during dusk and dawn than close to midnight (unpubl. data).

Male courtship behaviour attracts the female to the nest site and serves to secure the pair bond culminating with the laying of fertile eggs. A total of 275 distinct male behavioural events were summarized by courtship period intervals (Fig. 3); the male's activity level remained steady for the first 40 days of courtship and intensified substantially during the last 12 days prior to egg laying. The male's ear tufts were erect during all courtship behaviours possibly indicating a state of excitement or arousal.

Some behaviours were expressed more frequently during some intervals presumably to assist with pair formation for reproduction. Other behaviours, i.e. calling, were consistent over all intervals to attract the female from a distance, and/or to advertise to other males that the territory was occupied. Behaviours like turning and lying down (an incubation-like posture lasting a maximum of 1 min.) in the nest hollow were recorded more frequently in the later intervals. Dancing displays were confined to the early intervals prior to the female visiting the nest site (see female behaviour below) whereas conversations (i.e. relatively quiet vocalizations uttered when mates are close such as "buh-ju-dugge-dugge", see Mebs & Scherzinger 2008) and ritual copulations (Table 5) were recorded when the female was also at the nest site during the last interval. Some of the male's behaviours at the nest site implied that the female was present nearby but outside the camera's viewing field, i.e., duet vocalizations.

On relatively few occasions the male briefly visited the nest site with prey and then departed with it; a behaviour interpreted as a courtship "display of prey" (Table 5, Fig. 3). The male transferred prey twice before the female appeared to have accepted the nest site (see below) and five times shortly before egg laying. This behaviour is generally associated with the formation and maintenance of pair bonding in birds of prey (Marks et al. 1999). However, the small number of prey transfers and their timing suggested that other male courtship behaviours, such as visual and acoustic signals, may be a more important means to attract females to the nest site. During the last 3 weeks of the pre-laying period the male spent considerable time during longer visits laying down in the nest in a simulated incubation position and often making scratching movements or removing small objects from the nest site (Table 5).

Eurasian Eagle-owl copulations were commonly observed during surveys in the study area in the weeks before egg laying, most often at dusk on the owls' favourite perches (Harms 2016). Several copulations were recorded and captured on HD quality video which revealed that no contact of the birds' cloacae occurred during these early ritual (i.e. incomplete, *pro forma*) copulations. Ritual copulations were also recorded at the nest site in advance of egg laying (Fig. 3) and may function to strengthen pair bonds, synchronize pair behaviour and physiology, and ensure effective fertilization of the eggs.

Concurrent dusk surveys documented that by the end of January the male Eurasian Eagle-owl had moved about 600 m from a daytime forest roost to an ivy-covered oak tree closer to the nest site (Fig. 4) which it used through the courtship, incubation and a major part of the chick rearing periods (unpubl. data).

Female courtship period behaviour

The female was less active than the male, visiting the nest site 29 times on 18 nights of the 52-day courtship period, and one-half of the 9:35 h spent at the nest occurred in the last 12 days before egg laying (Table 6). Visits of different duration were more evenly spaced across the period than the male's but visits exceeding 60 min (n = 5, total duration

Table 5 - Description of courtship behaviours of a male Eurasian Eagle-owl (*Bubo bubo*) as captured on IR-video recordings in the pre-incubation period in 2014-2015, at a nest site in Baden-Württemberg, Germany.

Tabela 5 - Descrição dos comportamentos de corte de um macho de bufo-real (*Bubo bubo*) conforme gravações de vídeo infravermelhos no período de pré-incubação em 2014-2015, num ninho em Baden-Württemberg, Alemanha.

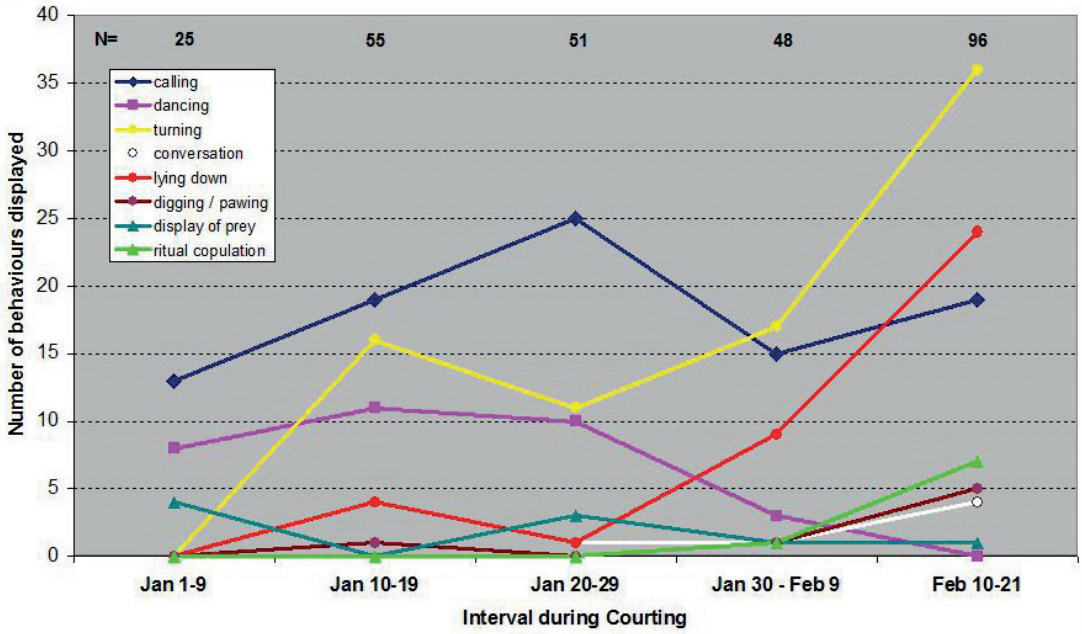
TYPE	DESCRIPTION
calling	repeated calling, inflated white throat clearly displayed, mostly combined with flashing or erect tail
turning	360° turn on the nest site, usually with tripling feet, often in bowed posture and with erect tail
tail whipping/spreading	excited repeated upward flashing of the tail/spreading of tail feathers
dancing	moving about the nest site, often in combination with turns, bows and calls, or shuffling feet
scratching in nest hollow	digging, scratching the surface of the nest site to deepen a shallow hollow for the placement of the eggs, often combined with turns and calls
cleaning nest site or hollow	removing small objects up to the size of eggs from the nest or hollow (particularly pieces of rock with sharp edges which may be harmful to eggs)
conversation	acoustic interaction of male and female when close to and facing each other, often with bowed head or displaying inclined posture
lying down in the nest hollow	lying down in the nest hollow lasting a maximum of 1 min.; may be combined with calls or cleaning activity
simulated incubation	lying down in the nest hollow, often preceded by turning and shuffling; extended duration (10 to >60 min) in an egg incubation-like posture
display of prey	male brings prey item to the nest site, offering or displaying it; may be combined with supportive calls; male departs from nest site with prey
offering & transfer of prey	male landing on nest site with prey item (usually held in beak), immediately followed by the female landing, offering prey to female in bowed posture, transfer of prey beak to beak; may be combined with conversation following transfer; male departs shortly (20-60 sec) after transfer
ritual copulation	copulation attempts without apparent cloacae contact, may occur several weeks before egg laying
copulation	copulations with apparent cloacae contact within the egg laying period leading to fertilization of eggs

6:15 h) accounted for more than 65% of the female's presence at the nest site (Table 7). When and how the female first responded to the advertising behaviour of the male, and when and by which behaviours did the female indicate a decision to accept the nest site were of interest.

The female first appeared at the nest site on 14 January 2015 after the male had been dancing (Table 5) for 2 min and which he continued for another 3 min after the female arrived. Following the male's departure, the female walked about the nest site, inspecting it, and started cleaning it. During the female's 10 min visit she repeatedly called (likely answered by the nearby male). The male returned to the nest 1:30 min after her departure, danced for 2:48 min and also cleaned

Figure 3 - Number and temporal distribution of recorded principal male Eurasian Eagle-owl (*Bubo bubo*) courting behaviours displayed at a nest site in Baden-Württemberg, Germany in 2014-2015.

Figura 3 - Número e distribuição temporal dos principais comportamentos de corte do macho de bufo-real (*Bubo bubo*) exibidos num ninho em Baden-Württemberg, Alemanha, em 2014-2015.



the site and briefly laid down in nest hollow. The male's post female visit behaviour may imply that the female was nearby watching.

The following night (15 January 2015) the female visited the nest for 33 sec and received a prey item from the male, and later again for 18:29 min when she inspected and cleaned the site. Video recordings showed that the female followed the male to the nest site for 18 of 29 female visits, and included the six occasions when the male transferred prey to the female. On 21 of the female's 29 visits, the male departed shortly (avg. 1:31 min) after her arrival which may have provided the female enough room to perform pre-egg laying behaviours at the site: the nest site was approx. 60 cm wide and 25-40 cm deep (see Fig. 1 in Harms 2019a) and there was a solitary stone approx. 50 cm away that was used by either owl as a perch during the courtship period.

The female assumed a simulated incubation posture (Table 5) nine times, initially (18 January; 1, 5 & 9 February 2015) for short duration (3:27 to 26:35 min) and along with other more dominant behaviours. This increased in length to become the dominant behaviour in early evenings between 6-18 February 2015 (n = 5 events, each > 1 h).

For the first time on 18 February 2015 (i.e., less than a week before egg laying), the female spent time at the nest site during daylight: At 17:19 (38 min before sunset) she was in a simulated incubation position in the hollow when I arrived to exchange batteries. The female left the nest site at 18:20:40 after a minimum 70 min simulated incubation session. She returned to the nest at 5:08:20 the next day for 2:15 min to receive prey from the male.

On 18 & 20 January, and twice on 6 February, the female landed at the nest site,

Figure 4 - Male Eurasian Eagle-owl (*Bubo bubo*) perched at a daytime roost close to its nest site in Baden-Württemberg, Germany in May 2015 during the chick rearing period.

Figura 4 - Macho de bufo-real (*Bubo bubo*) num poiso diurno próximo do ninho em Baden-Württemberg, Alemanha, em maio de 2015, durante o período de juvenis no ninho.

Table 6 - Quantitative aspects of nest site visitation by a female Eurasian Eagle-owl (*Bubo bubo*) as captured on IR-video recordings in the courting period (January 2015) in Baden-Württemberg, Germany.

Tabela 6 - Aspetos quantitativos das visitas ao ninho por uma fêmea de bufo-real (*Bubo bubo*) conforme gravações de vídeo de infravermelhos durante o período de corte (janeiro de 2015) em Baden-Württemberg, Alemanha.

FEMALE ACTIVITY DURING COURTING	JAN 1 - 9	JAN 10 - 19	JAN 20 - 29	JAN 30 - FEB 9	FEB 10 - 21	CUMU-LATED
Calendar days	10	10	10	10	12	52
Recording days	9	5	5	8	10	37
Nights with female presence	1	4	1	5	7	18
Number of visits	1	6	3	9	10	29
avg. number of visits per night with presence	1	1.5	3	1.8	1.4	1.6
Duration of all visits [h:min:sec]	1:20:10	0:43:57	0:13:11	2:34:09	4:43:17	9:34:44
Duration of all visits, cumulated [h:min:sec]	1:20:10	2:04:07	2:17:18	4:51:27	9:34:44	
Duration of all visits [%]	13.9	7.6	2.3	26.8	49.3	100
Duration of all visits, cumulated [%]	13.9	21.6	23.9	50.7	100	
avg. duration of visits per night with presence	1:20:10	0:10:59	0:13:11	0:30:50	0:40:28	0:31:56
Number of visits <5 min	0	3	2	3	3	11
Number of visits >60 min	1	0	0	1	3	5

Table 7 - Number and duration of nest site visits by a female Eurasian Eagle-owl (*Bubo bubo*) in Baden-Württemberg, Germany as captured on IR-video recordings in the courting period (January 2015).

Tabela 7 - Número e duração das visitas ao ninho por uma fêmea de bufo-real (*Bubo bubo*) em Baden-Württemberg, Alemanha, conforme gravações de vídeo de infravermelhos durante o período de corte (janeiro de 2015).

Duration of visit [min]	<1	>1 - 5	>5 - 15	>15 - 60	>60	cumulated
Number of visits	4	7	7	6	5	29
% of visits	13.8	24.1	24.1	20.7	17.2	100
% of visits, cumulated	13.8	37.9	62.1	82.8	100	
Duration of visits [h:min:sec]	0:01:35	0:22:13	1:07:22	1:48:09	6:15:25	9:34:44
% duration	0.3	3.9	11.7	18.8	65.3	100
% duration, cumulated	0.3	4.1	15.9	34.7	100	

Figure 5 - Number and distribution of Eurasian Eagle-owl (*Bubo bubo*) nest site visits per night during the courtship period (N=139, male; N=29, female) in Baden-Württemberg, Germany in 2014-2015.

Figura 5 - Número e distribuição de visitas ao ninho pelo bufo-real (*Bubo bubo*) por noite durante o período de corte (N = 139, macho; N = 29, fêmea) em Baden-Württemberg, Alemanha, em 2014-2015.

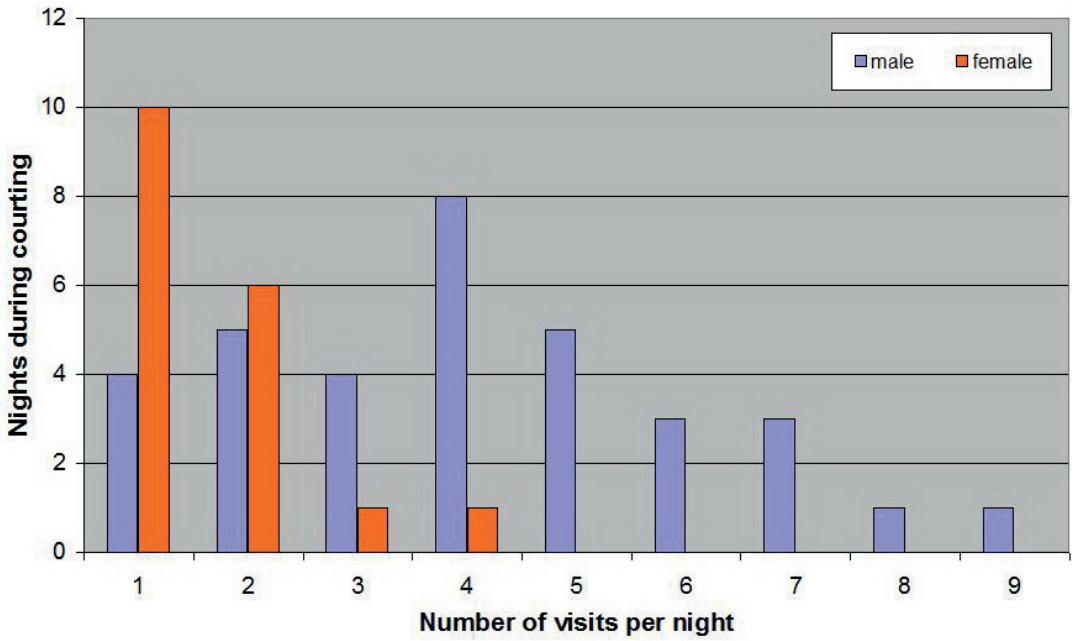


Figure 6 - Number and temporal distribution of Eurasian Eagle-owl (*Bubo bubo*) nest site visits recorded during the courtship period in Baden-Württemberg, Germany in 2014-2015.

Figura 6 - Número e distribuição temporal das visitas ao ninho pelo bufo-real (*Bubo bubo*) registadas durante o período de corte em Baden-Württemberg, Alemanha, em 2014-2015.

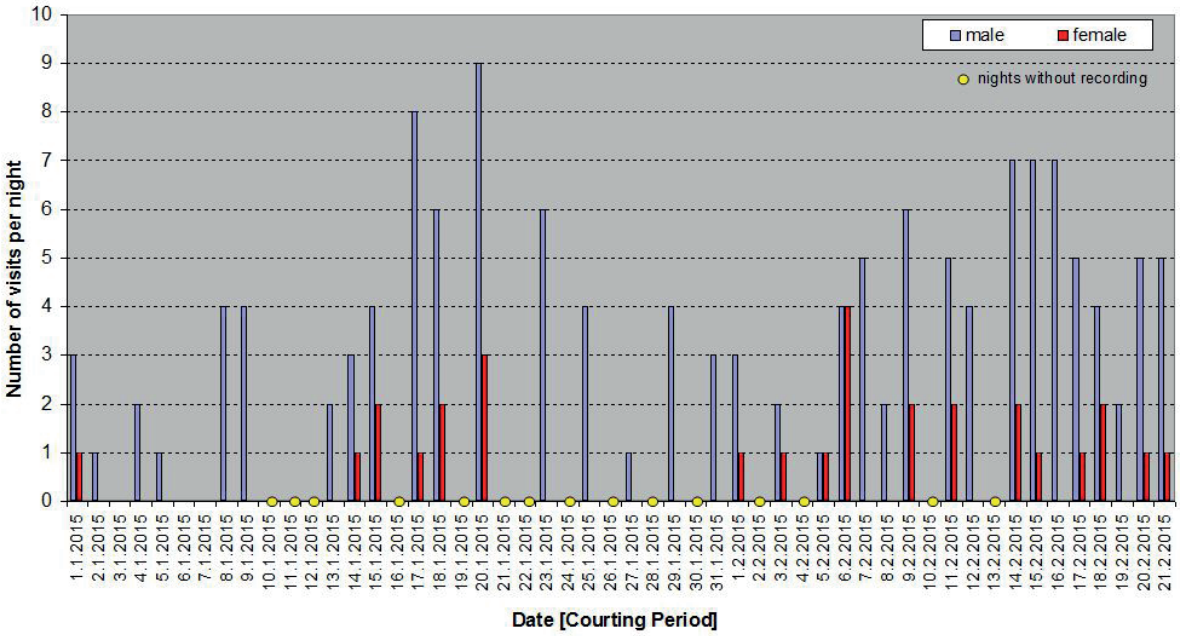


Table 8 - Comparison of male and female Eurasian Eagle-owl (*Bubo bubo*) behaviour as captured on IR-video recordings in the courtship period in 2014-2015 at a nest site in Baden-Württemberg, Germany.

Tabela 8 - Comparação do comportamento do macho e da fêmea de bufo-real (*Bubo bubo*) conforme gravações de vídeo de infravermelhos durante período de corte em 2014-2015 num ninho em Baden-Württemberg, Alemanha.

	MALE	FEMALE
Number of days present	34	18
Total number of visits	139	29
Avg. number of visits per night	4.1	1.6
Total duration of visits [h:min:sec]	47:44:22	9:34:44
Avg. duration per visit [min:sec]	20:36	19:49
Shortest visit [sec]	4	15
Longest visit [h:min:sec]	5:11:19	1:25:35
Date of longest visit	Feb 15	Feb 6
Common time spent at the nest site [min:sec]	31:10	

followed within seconds by the male. Also, for the first time on 6 February, the female landed without being either preceded or followed by the male. However, only 15 seconds after the female left the male landed at the nest site, suggesting he was nearby watching the female's on-site visit.

Comparison of male and female behaviour during the courtship period

The male spent five-fold more time at the nest site and visited it five times more often at nights than the female during the courtship period (Table 8). The male and female spent 31:10 min together at the site, corresponding to approx. 1% of the male's and slightly less than 6% of the female's total time at the nest.

Differences in male and female behaviour distribution patterns include the frequency distribution in the number of visits per night (Fig. 5) and in the phenology of their visits during the courtship period (Fig. 6). The male increased his activities from early January and this peaked on 20 January, which coincided with the female's first cluster of nine visits to the nest site beginning 14 January. Between 21 & 31 January there was a gap of 11 consecutive nights when the female was not present during which time the male made 18 visits and continued to advertise the nest site. Additional, non-recorded, observations suggest an explanation for this gap and are presented below (Conclusions). On 1 February the female started to visit the nest site again after which courtship behaviours increased for both the male and female (Fig. 6). A coordinated increase in nest visits on 6 February suggested a strengthening in the male and female's pair bond and final selection of this nest site which culminated in the laying of the first egg on 22 February.

Both the male and female cleaned the nest site while exhibiting simulated incubation behaviour later in the courtship period. During this behaviour the male indiscriminately, or perhaps symbolically, removed a variety of objects including stones, pieces of wood, and leaves whereas the female appeared to be more selective or practical and removed small rocks with sharp edges from the nest hollow. The latter objects may be more likely to damage eggs and/or to cause discomfort to the incubating female.

The courtship period ended with the laying of the first egg on 22 February when the female remained in the nest during the day.

The female's presence at the nest during daytime hours is a fundamental change of behaviour and a strong signal that egg laying and incubation have begun.

Conclusions

This paper provides the first qualitative and quantitative examination of pre-courtship and courtship behaviour displayed by a pair of Eurasian Eagle-owls in the wild using extensive IR video recordings. A follow-up paper (Harms 2021) focuses on the pair's behaviour during the incubation period; an analysis of the chick rearing period is also available (Harms 2019). During the pre-incubation period more than 70% of the nights were captured providing a near complete chronology of reproductive behaviour for this nocturnal top avian predator. The analysis of the owls' cryptic nocturnal reproductive behaviour has become possible through the use of the IR video camera at a nest site under undisturbed natural outdoor conditions. While some of these results confirm previous observations, often derived from birds kept in captivity, others reveal some new and unexpected behaviours which deserve further comment and discussion.

The male's display and transfer of prey were expected to play a major role to attract the female to the nest site (Lack 1940, Smith 1960). Sharing food may be a strong signal of crucial values such as altruism or commitment in addition to demonstrating the male's fitness, which is indispensable during incubation and chick rearing when female and young are totally dependent upon the male's ability to provide enough food to sustain them (Harms 2018a, 2019). Yet only four food displays and two prey transfers were observed during courtship when the female is presumably choosing a nest site. This suggests that these behaviours play a lesser role in attracting the female to the nest site.

Nest site selection is a complex decision making process involving the exchange of a range of different signals between the male and the female. Male courtship behaviours other than feeding and food display, such as vocal and dancing displays, may be relatively more important to the female in this regard. These aspects of courtship rituals deserve more research, especially given that the acoustic component of the male's behaviour could not be evaluated fully in this study due to a lack of concurrently recorded sound due to technical reasons. Future research should focus on the strategies and mechanisms of mutual (cooperative) decisions in pair formation such as nest site selection, since they play a vital role in the reproductive process (Harms, in preparation) and many aspects of courtship behaviour remain unknown at this time.

Outstanding questions include if it was typical why the female did not visit the nest site until after seemingly excessive courtship behaviour effort by the male intended to guide her to the site. From past monitoring efforts, it was clear that the same female used this site in previous years. She would therefore be familiar with this site and other potential sites in the associated territory, yet the annual ritual courtship display phenomenon still seems to be critical to the selection of the same mate and nest site.

The prominence of the simulated incubation behaviour (Table 5) by the male, and the response by the female, were another unexplained discovery, especially given that egg incubation is not a male role in Eurasian Eagle-owl reproduction. It is possible that it serves as a stimulating signal for the female, as she responded to it with numerous extensive simulated incubation behaviours, especially in the late intervals of the courtship period. Her performance of this behaviour may have simply imitated (mirrored) the male's or it may be a self-stimulatory exercise in preparation for the upcoming nesting period or a signal to her mate indicating progress along the courtship process, or a combination of these purposes. The amount of time invested in this behaviour can be regarded as a measure of

its importance in the courtship process. Such interactions reveal that behaviours associated with courtship and decision making are still poorly understood at this time and deserve further research (Harms, in preparation).

The activity profile during courtship represented in Fig. 6 revealed a striking gap when the female did not appear in the recordings for 11 nights in a row in late January 2015. Observations I made in February and March 2016 help us understand the female's 2015 absence. In 2016, I was again following the activities of this pair of Eurasian Eagle-owls, identified with distinguishable visual features, using the nest-site camera. After a period of 'normal' courtship activities, the owls' activities dwindled and then stopped by the end of February. Again, the recordings offered little in terms of explanation, but their behaviour made it clear that the owls did not intend to nest at this site. Some weeks later, during an exploratory visit, I detected the female lying in a rock cavity about 25 m away from their 'regular' nesting site, and apparently incubating her eggs. Together, these observations in 2016 lead to a new interpretation of the owls' activities: apparently, they were courting at their regular nest site (captured by the camera) but were also exploring alternative sites such as the rock cavity (outside the camera's viewing field) for some time. In 2016, the owls chose to use the alternative rock cavity for their nesting; consequently, congruent with this decision, they stopped courtship at the 'regular' site (as reflected in the camera recordings). Most likely the owls exhibited similar behaviour, exploring alternative nest sites, in 2015 as well. For some time, in January 2015, the owls may have been turning their attention to the exploration of the rock cavity. While the female appeared to focus completely on the alternative site and temporarily discontinued her visits to the original site, the male kept visiting and advertising it - although at a reduced level of activity as shown in Fig. 6. Both sites had been used for raising chicks in previous years. Finally, both the male and female resumed courtship at the regular site once they had selected it for the 2015 nesting season. Based on her presence and absence, the female appeared to make the final nest site location decision while the male advertised possible sites. Consequently, the camera then captured a second peak of courtship activities during February 2015 (Fig. 6). This episode further demonstrates how IR video recordings may be employed in the study of nocturnal species as a tool to elucidate behavioural components associated with essential reproductive decision-making.

Whenever a study, such as this, deals with observations on one or few individuals, the important question arises: how much of observed behaviour is typical of the species versus unique individual variation? Most probably, what was observed was a combination of both, i.e. typical behaviours coloured by a special individual shaping ("Überformung"). The courtship behaviours, both previously known and new, of the pair of Eurasian Eagle-owls in this study culminated in successful reproduction, and therefore generate some forward-looking questions. Which behavioural components are fundamental in the canon of reproductive behaviours? Are courtship rituals simply spooled off like a film? How much variability is possible? How much individual colouring is permitted? Do long-time and reproductively experienced pairs run 'the full program' of behaviours year by year, or do they take short cuts? Do first-time breeding pairs display a more varied repertoire of behaviours than established pairs with years of breeding experience? What courtship behaviours are displayed when an experienced owl mates with an inexperienced or new partner? What are the stripped-down, key behavioural elements of a functional courtship that leads to reproductive success? Similarly, behaviours during the incubation period (Harms 2021) should be scrutinized for a better understanding of what are the essential elements of general validity versus those shaped by coincidence, by individual and situational factors.

Such questions can only be addressed if

more recordings of on-site observations are subject to detailed analyses such as presented in this study. Through the comparison of different versions of complex behaviours we can extract the essentials and begin to understand what constitutes the set of indispensable (*archetypical*) behaviours and collect the full range of individual variability. To this end I have made recordings during courtship, incubation and chick rearing at a different location with another pair of Eurasian Eagle-owls, now awaiting evaluation (Harms, in preparation). It is with these goals in mind that I would like to encourage webcam operators to engage in a comprehensive and systematic analysis of their recorded video materials in order to promote a deeper knowledge of the complexity and diversity of owl reproductive behaviours.

Note: Video clips showing selected scenes extracted from the recordings at the Eurasian Eagle-owl nest site may be viewed on YouTube, channel "cth-ornitho" (https://www.youtube.com/channel/UCikFnM7cQEzD-pCkM8gywvmQ). Additional information and published articles are available for viewing or download on www.researchgate.net/profile/Christian_Harms2/

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