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The acoustic communication of the Eurasian Green Woodpecker *(Picus viridis)*

Kyle Turner[1*], Gerard Gorman[2] & Danny Alder[3]

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Abstract Woodpeckers, having a fairly well-defined range of acoustic signals, offer a valuable opportunity to link acoustic repertoires to behavioural observations. Instrumental and vocal sounds from more than 70 individual Eurasian Green Woodpeckers were analysed using 305 sound recordings. Eighteen separate acoustic signals are described, together with field observations of associated behaviour. Sixteen are illustrated by clear spectrograms supporting the phonetic descriptions. With one exception, calls consisted of repeated elements, with the first element often containing varying degrees of emphasis. Variation within call types, especially the advertising call, differentiated individuals and their motivation and did not appear to be regionally significant. Instrumental signals, while soft and easily overlooked, constituted an important intimate communication between breeding pairs.

Keywords: woodpeckers, instrumental sounds, vocal sounds, signal characteristics, call types, drumming, tapping

Összefoglalás A harkályfélék jól elkülöníthető akusztikus jelzései lehetővé teszik azok viselkedési megfigyelésekkel való összekötéseit. 70 zöld küllő egyedtől származó, összesen 305 hangfelvételen található dobolási és vokális hangokat elemeztünk. 18 hangtípust írtunk le a terepi vizuális megfigyelésekkel párosítva, melyek közül 16-hoz spektrografikus elemzést is közreadunk. Egy kivételével a hangjelzések ismételt elemekből álltak. Az egyes hangtípusok varianciáját az egyedi eltérések, a belső állapot is meghatározták, de lényeges földrajzi hatás nem mutatható ki. A tanulmány felhívja a figyelmet arra, hogy a külső felületen keltett halkabb hangok a fészkelő párok egymás közötti kommunikációjában lehetnek fontosak.

Kulcsszavak: harkályfélék, külső felületen képzett hangok, vokális hangok, hangjellemzők, hangtípusok, dobolás, kopogás

[1] Independent Bio-acoustics Researcher, St. Andrews Farm, Woodbridge Lane, Bedchester, Shaftesbury, Dorset, SP7 0BF, United Kingdom
[2] Independent Picid Researcher, Hungarian Woodpecker Working Group, MME Központ, 1121, Budapest, Költő utca 21., Hungary
[3] Independent Ecologist, 12 Elm Close, Motcombe, Shaftesbury, Dorset, SP7 9HN, United Kingdom
** corresponding author, e-mail: kyleturner@orange.fr*

Introduction

The global distribution of Eurasian Green Woodpecker *(Picus viridis)* falls entirely within the Old World and mostly within the Western Palearctic region. Around 95% of the total population is considered to be in Europe (BirdLife International 2020). Populations are resident, non-migratory and usually sedentary, although some short-range post-breeding dispersal of juveniles takes place (Glutz von Blotzheim & Bauer 1994, Winkler *et al.* 1995, Gorman 2004, 2020).

The species is polytypic, with three subspecies generally recognised: *viridis* which is found in Britain, southern Scandinavia, continental Europe and western Russia; *karelini* in

Italy, the southern Balkans, the Caucasus and eastwards to Turkmenistan; and *innominatus*, which is occurs solely in the Zagros Mountains in Iran and Iraq (Gorman 2014, 2020). All of the birds which were recorded for this paper were the nominate *viridis* subspecies. Eurasian Green Woodpeckers inhabit a variety of sparsely wooded habitats across this range, which covers three eco-climatic regions: the temperate, Mediterranean and boreal zones. Typical breeding habitats occupied include open forests and woodlands; riparian woods; hedgerows with large trees; parkland; orchards and large gardens. Deciduous trees are habitually utilised, but in some regions mixed deciduous-coniferous woodlands are occupied. Closed forests are avoided. In all areas a home-range requires grasslands adjacent to the breeding territory where birds can forage for terrestrial ants (Alder & Marsden 2010). In Europe, both lowlands and uplands, to around 2,000 m, only occasionally higher, are inhabited (Gorman 2020). Although there have been declines locally, often owing to grassland and/or wooded habitat degradation, the overall trends for this species are positive and it is not considered to be threatened. In the IUCN Red List of Threatened Species, Eurasian Green Woodpecker is classified as Least Concern (BirdLife International 2016).

To date, the most detailed study of the voice of the Eurasian Green Woodpecker was carried out in the 1950s and 1960s and was summarised in a later publication which described six calls and two instrumental signals (Blume 1955, 1961, 1996). This study, together with other historical observations, formed the most comprehensive, contemporary account available (Cramp 1985) in which vocal signals were found to be the same and used equally by both sexes throughout the year, while tapping and drumming were rare. Another account featured eight calls and two instrumental signals and described the 'laughing' call as the most familiar and easily identifiable of the species (Glutz von Blotzheim & Bauer 1994).

Instrumental signals

Drumming by woodpeckers consists of a rapid, repetitive series of strikes with the bill on a substrate and is distinct from the mechanical sounds produced during foraging or cavity excavation (Pynnönen 1939). When performed loudly and in series it is a unique method of communicating information about ownership of suitable breeding sites (Winkler & Short 1978) and serves to establish and maintain the breeding pair (Gorman 2004, Tremain *et al.* 2008). As a long-distance signal it transmits this information to territorial neighbours and potential rivals. By contrast, soft drumming is used by some species close to potential nest holes (Florentin *et al.* 2017) and in Middle Spotted Woodpecker *(Dendrocoptes medius)* appears to signal a motivation for breeding (Turner 2020). Tapping, when performed in discrete bursts of more or less equally spaced strikes is termed 'demonstrative tapping' (Blume 1996) and acts as a signal, either to advertise a potential nest site or to encourage a change-over during excavation or incubation. It is always slower than drumming and does not form a 'roll', exceeding the minimum of 90 milliseconds between strikes which divides the two forms of instrumental communication (Florentin *et al.* 2016, Turner & Gorman 2021). However, according to Glutz von Blotzheim and Bauer (1994) instrumental signals have only negligible importance in communication between Eurasian Green Woodpeckers.

More recently, bioacoustics has become an important tool for biologists and conservationists, improving our understanding of the natural world (Shaw *et al.* 2021). High quality recordings of species coupled with detailed observations are especially valuable in revealing new behaviour (Dalziell & Welbergen 2016) and, with the emergence of digital technology, have increased the opportunities for ornithologists to contribute to science (Vella *et al.* 2021) providing scope to review and revise our understanding of vocalisations and auditory signals for a range of species including woodpeckers (Węgrzyn *et al.* 2021).

When describing the acoustic repertoire of any species an understanding of behavioural contexts can provide functional labels, although calls having more than one function (for example: contact and alarm) are problematic. While the potential for ambiguity inherent in phonetic descriptions limits their usefulness, when combined with clear spectrogram images they enable effective cross-referencing. In particular, a thorough knowledge of the repertoire of any species facilitates the evaluation of similarities in the form of calls and the situations in which they are used (Winkler & Short 1978).

Vocal signals

In common with other members of the Picidae, Eurasian Green Woodpecker vocalisations generally consist of a series of repeated elements and are not learned (Winkler *et al.* 1995). This includes what is sometimes referred to as the 'song' which, while it is largely restricted to the breeding season (Cramp 1985), lacks the complexity of rhythm and modulation more typical of species with learned songs (Catchpole & Slater 2008), and is more suitably described as an 'advertising call'. It is nevertheless more ritualized and idiosyncratic than its other calls, having a slightly more complex and variable structure which should enable individual recognition by partners and young (Glutz von Blotzheim & Bauer 1994). Its distinctive 'laughing' quality makes it one of the best-known and easily recognized bird sounds in Europe and one of the few to have its own colloquial name '*Yaffle'* in English. The individual elements of the advertising call visible on spectrograms are characterized by variables of shape, length, pitch, emphasis, speed of delivery and extent of repetition. In seven examples from Scandinavia, advertising calls were slower, decelerated more and were lower in pitch (Fauré 2018). Interestingly, although they are geographically separated, Eurasian Green Woodpeckers in Britain do not seem to call differently from birds in continental Europe. The only other European species with a similar advertising call is the closely related Iberian Green Woodpecker *(Picus sharpei)* which was formerly regarded as conspecific with *viridis*. In southwest France and northeast Spain, where the two species sometimes interbreed, it is often difficult to separate them in the field by their advertising calls since although *sharpei*'*s* consists of only one dominant frequency, *viridis* also has advertising calls with a single dominant frequency in addition to its more typical double version (Fauré 2013).

Other calls of *viridis* contain short and relatively simple elements which are usually repeated in irregular series (Gorman 2020). A written interpretation of calls ranging from '*Whurdles'* to '*Wickas'* contains detailed measurements of component characteristics but does not employ spectrograms, concentrating instead on comparisons across woodpeckers worldwide (Short 1982).

The aim of this study was to present an up-to-date account of the fullest range of acoustic signals employed by the Eurasian Green Woodpecker based on an extensive collection of high-quality sound recordings. Production of spectrograms from this source has enabled an objective analysis, providing statistical comparison of signal types to augment functional and phonetic descriptions.

Materials and Methods

Despite its relatively common status throughout Europe, the Eurasian Green Woodpecker is a difficult bird to approach. It is very vigilant and alert while foraging and quick to move away when approached, whether on open ground or in woodland. Fieldwork was carried out in the spring to establish areas with potential for nesting, where observations would be possible during recording sessions. Sound recordings were made of instrumental and vocal signals produced by the species in England, France and Hungary, mostly from within thirty metres. No 'play-back' of calls was used. The spectrograms used in this study were selected from 305 recordings of Eurasian Green Woodpecker extracted from the archive of the first author. The majority of recordings were made since 2001 and were obtained during the period from March to July, the most vocal period for this species. Before 2005, recordings were made on a Kenwood DMC-G7R Minidisc @ 44.1kHz/16bit (Atrac 4.5) using a pair of Sennheiser MKH 105 microphones in a 50×13cm parabolic reflector. Subsequently, a pair of DPA 4051 compact microphones were used into a Sound Devices 722 file recorder at 44.1kHz/16bit and since 2018 at 44.8kHz/24bit. Nest recordings were made with a pair of DPA 4060 miniature microphones mounted on an extendable roach pole. Searches were also made of the xeno-canto online bird sound resource (www.xenocanto.org) in order to increase the number of individuals available for analysis of drum-rolls(1) and the autumn call(2). The autumn call was thought to be a variant on the advertising call (Cramp 1985) and thus needed sufficient recorded and dated examples for comparisons to be made.

Following Short (1982), all recordings were analysed focusing on the repeated elements which formed each acoustic signal. Lengths were measured in milliseconds (ms) and pitch (fundamental frequency) in kilohertz (kHz) on Cool Edit Pro II software, processed as 32bit PCM wave files with Blackman Harris 256 resolution. For instrumental signals, we assessed duration, number of strikes, average interval between strikes and changes in tempo. The amplitude of strikes was measured by pulse train analysis using Avisoft SASlab lite. For vocal signals, we assessed the number of elements in a call, the number per second, changes in tempo and the length and pitch of individual elements. Spectrograms were produced using Raven Lite 2.0 (Cornell) with the coloured elements obtained using Gimp 2.10.28 photo editing software by selecting the stronger tones. Exploratory data analysis was carried out using Microsoft Excel 2016. When not sound-recorded, acoustic communications heard outside the breeding season were logged, together with observed behavioural contexts. In our paper, we use 'advertising call' in place of 'song'. Where averages are given, ranges are shown in parenthesis. 'Element' is used to define the individual components of calls. Phonetic descriptions are based on Cramp (1985).

Results

Instrumental signals

Three signal types performed by mechanically striking wood were recorded.

(a) ***Drumming (n=101)***
In an analysis of drum-rolls from 16 individual birds (4 from the online xeno-canto archive) the average for the duration of rolls was 1220 ms (276–2322), with an average of 24 strikes (5–45) per roll given at 20.7 strikes per second (17.5–26.1). Average intervals between strikes were 51 ms (42–61) with an overall deceleration from 46 ms (34–58) between the first two strikes to 64 ms (47–84) for the last two strikes *(Figure 1)*, excluding four rolls that petered out into tapping. Birds drummed without selecting acoustically resonant substrates and drum-rolls were

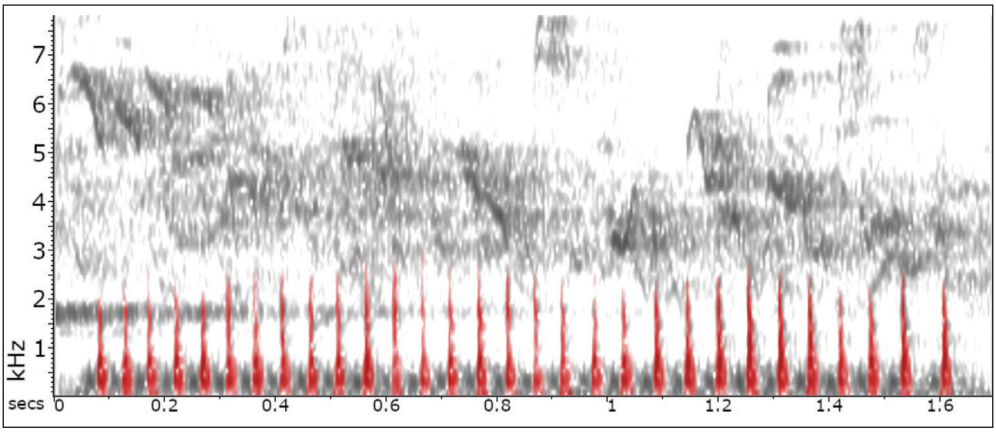

Figure 1. Drum-roll, showing a decelerating strike rate. Lot, France. 16.03.2002.
1. ábra Csökkenő tempójú dobolási sorozat. Lot, Franciaország. 2002.03.16.

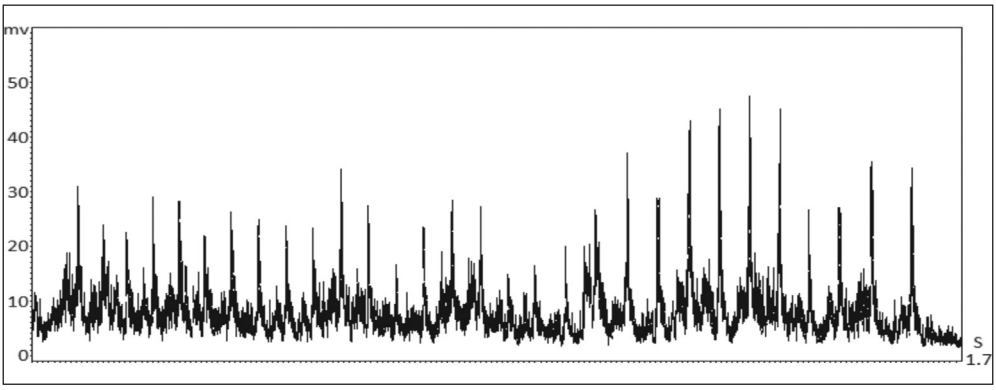

Figure 2. Pulse train analysis – the same drum-roll as *Figure 1*, showing the variable amplitude of strikes (measured in millivolts on the Y axis) throughout the roll
2. ábra Impulzussorozat elemzési ábra, amely az *1. ábra* dobolási sorozatáról készült, és amely mutatja az eltérő amplitúdójú impulzusokat

often barely audible. They were performed close to a potential nest hole and usually involved both birds in a loose duet, serving as an intimate communication for bonding between the pair. No examples of loud drumming, as a means of claiming or defending a territory were heard. All signals aimed at potential rivals were communicated vocally. Soft, isolated drum-rolls were occasionally given during excavation, and one was heard during a series of advertising calls.

Table 1. Strikes per roll for 12 different individuals and positions of the weakest and strongest strikes within each roll.

1. táblázat 12 egyed dobolás sorozatának elemzése a leggyengébb és legerősebb ütések sorszámának megadásával

Individuals	Strikes	Weakest	Strongest
1	30	15	24
2	23	6	20
3	18	10	16
4	37	3	29
5	30	27	18
6	30	2	31
7	36	4	31
8	20	3	1
9	35	4	11
10	26	1	9
11	29	7	20
12	29	29	1

Pulse train analyses of relative strike amplitude throughout drum rolls of different individuals (n=12) revealed a lack of any regular pattern in the loudness of the strikes *(Figure 2)*. The rolls ranged from 18 to 36 strikes but despite a predominance of louder strikes in the second half in 9 of the rolls, there was no consistency in the overall rhythm. This is illustrated by the irregular positions of the weakest and strongest strikes within each roll *(Table 1)*.

In an example of a pair drumming quietly (audible only within ten metres) in a potential nesting tree over a period of 47 minutes, one bird drummed 17 times, with an average of

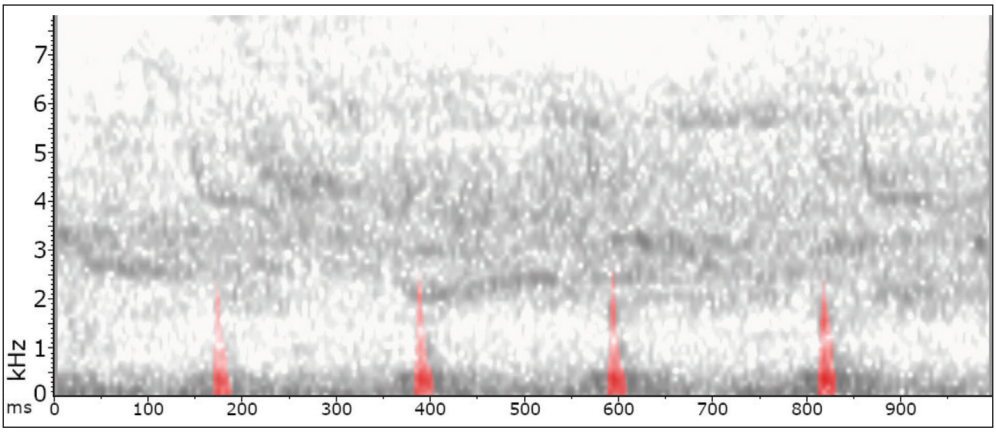

Figure 3. Demonstrative tapping, given during a drumming duet. In this example, the four very soft taps were fairly evenly spaced, with average intervals of 215 ms, while the force of each strike increased slightly. Lot, France. 16.03.2002.

3. ábra Egy dobolási duett közben produkált „tapping" – kopogás. Ebben a példában a négy halk koppanás egyenletesen követi egymást, átlagosan 215 ms idővel, míg a koppanások erőssége enyhén nő. Lot, Franciaország. 2002.03.16.

27.3 strikes per roll (7–39) while the other drummed 25 times with an average of 25.8 strikes per roll (6–36). Eight quiet advertising calls were also given early in the sequence (3 by the first bird and 5 by the second) and one bird gave a series of 14 very soft '*Peeuw*' calls *(Figure 14)* after 9 minutes (Lot, France. 16.03.2002).

(b) ***Tapping (n=22)***
Bursts of demonstrative tapping, containing 4 or more strikes, were heard at three nests, showing average intervals of 186 ms (124–236) at 7.5 per second (4.5–9.7). The maximum number of strikes in a burst was 6. The tapping was performed during the selection and excavation of the nest hole and was usually interspersed with drumming which it matched in quietness *(Figure 3)*. A single burst of 3 strikes was given by a bird emerging from its roost hole (Lot, France. 02.05.2010).

(c) ***Tapping/drumming combinations (n=6)***
In addition to the four drum-rolls that had longer strike intervals at the end, six examples of very soft combinations of tapping and drumming were recorded during courtship drumming duets at one nest site. In each case the taps were slightly louder, and the drum-rolls were shorter than average at 17.7 strikes per roll. Two examples were given within 4 ½ seconds after 6 minutes of drumming and demonstrative tapping. The first started with 4 taps (117,103 and 101 ms apart) leading into a roll of 22 strikes (av. int. 44 ms) *(Figure 4)*. The second started with 2 taps (104 ms apart) leading into a roll of 19 strikes (av. int. 46 ms).

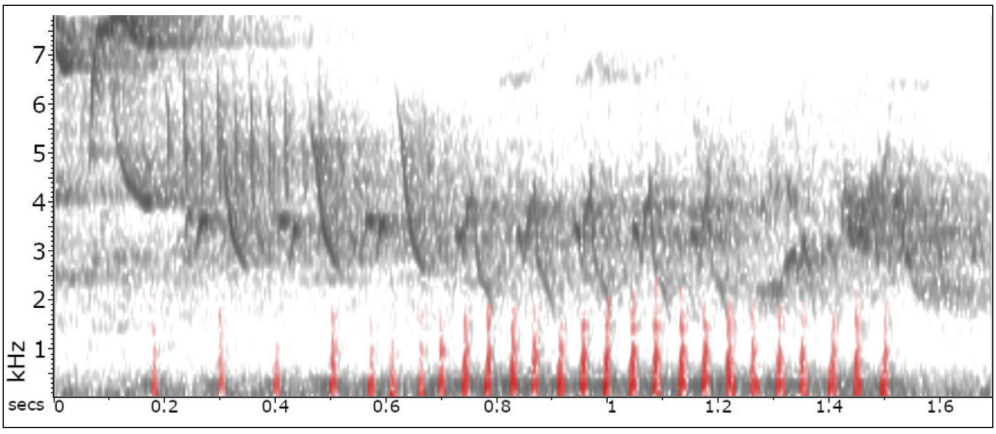

Figure 4. Tapping/drumming combination. Four taps preceding a drum-roll of 22 strikes. Lot, France. 16.03.2002.

4. ábra „Tapping" (kopogás) / „drumming" (dobolás) kombináció. Négy kopogás után 22 elemből álló dobolási sorozat látható. Lot, Franciaország. 2002.03.16.

Vocal signals

Ten distinct vocalisations were heard from adult Eurasian Green Woodpeckers *(Table 2)*, three transitioning calls were heard from nestlings and two from juveniles.

Table 2. Adult call types, functions and phonetic destriptions
2. táblázat Felnőtt egyedektől származó hangtípusok, azok funkciói és fonetikus leírásuk

Call ref.	Call Name	Call Function	Phonetic Description
(a)	Advertising Call, (Song, Yaffle, Laughing Call)	Territorial proclamation, Pair formation, Contact	*Kew, Klu*
(b)	Regular Call	Contact, Arrival, Departure, Alarm	*Tiew, Kew, Teuk*
(c)	'*Kuk*' Call	Contact, Alarm	*Kuk, Kik*
(d)	Flight Call	Movement within home-range	*Kjaek, Kjeuk*
(e)	Flight Alarm Call	Fleeing from predator	*Kju-kju-kjuk*
(f)	Autumn Call	Static (declaration of immature independence?)	*Kjaek, Kjeuk*
(g)	Threat Call	Conflict, Antagonism	*Kjaik*
(h)	'*Peeuw*' Call	Courtship, Presence at nest hole	*Peeuw, Piu, Pweep, Tche-uw, T-we*
(i)	'Wa' Call	Presence at nest hole	*Wa*
(j)	Squeak Call	Frustration, Anxiety	*We-we-we*

(a) ***Advertising Call (Song) (n=50)***
Analysis of advertising calls recorded in 31 different territories showed 80% dropping in pitch while 10% remained flat and 10% rose. There was an overall average reduction of 0.23 kHz between the fundamental frequencies of the first and second elements. Two calls rose and then fell. The average speed, measured in the middle of the calls was 5.9 elements per second (4–7.5). Calls as a whole decelerated from an average interval of 76 ms (43–147) between the first two elements to 94 ms (51–164) between the last two elements. The length of elements reduced through calls by an average of 47 ms from 123 ms (60–176) to 76 ms (23–127). Five calls contained elements of increasing length and two remained constant. With the possible exception of the first example in *Figure 7*, the peak in frequency came after the middle of the element. In general, elements reduced in amplitude throughout the call. The length of calls was greater during the breeding period with an average of 13.8 elements during March, April and May (n=205) compared to 5.2 (n=29) for the rest of the year. Unpaired birds vocalised more frequently. One individual, moving around its territory called once every 30 seconds at its most visited tree, giving 12 calls with an average of 15.6 elements (8–25) in six minutes (Dorset, England. 18.04.2021). In December and January, isolated, short, piping calls were occasionally heard. Insufficient gender-identified advertising calls were obtained that could point to a reliable separation based on differences in characteristics (see Discussion).

Advertising calls consisted of a series of '*Kew'* or *'Klu'* elements showing as inverted 'U's in their purest, single dominant frequency form *(Figure 5)*. Increased motivation, especially during the competitive period of establishing a breeding pair, led to a more frequent repetition and often resulted in sharper elements, producing spikes at the highest frequency in spectrograms *(Figure 6)*. Greater variation was achieved when both shapes occurred in a single call.

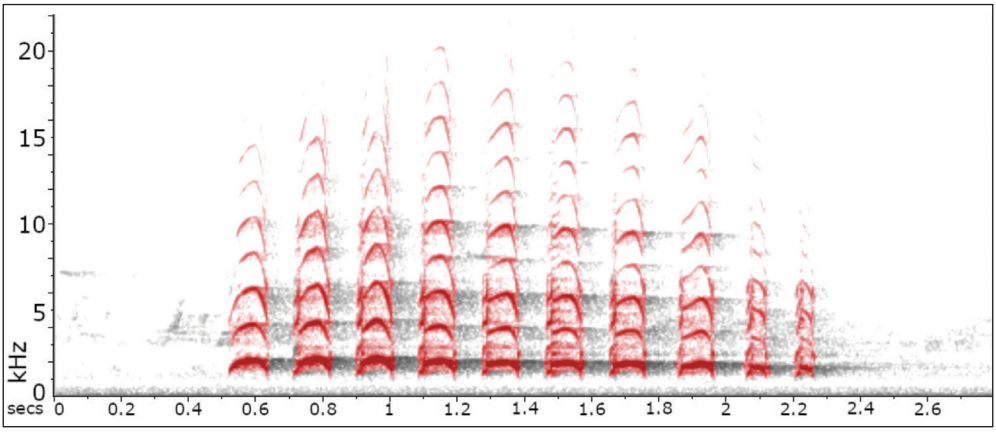

Figure 5. Advertising call, showing simple inverted 'U' elements plus two smaller, quieter and more pointed elements at the end. Dorset, England. 02.02.2007.

5. ábra „Advertising call", nászidőszaki hang, egyszerű, fordított 'U' alakú elemek, a végén két rövidebb elemmel. Dorset, Anglia. 2007.02.02.

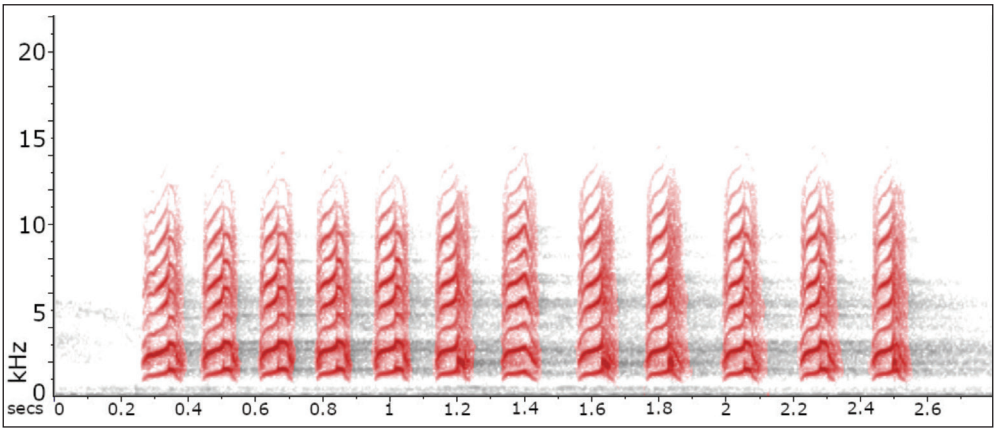

Figure 6. Advertising call, showing sharp elements of fairly consistent length and shape but with a clear deceleration. Lot, France. 19.03.2005.

6. ábra „Advertising call", nászidőszaki hang, éles hangzású, azonos hosszúságú elemekkel, csökkenő tempóban előadva. Lot, Franciaország. 2005.03.19.

Calls were loudest and highest pitched at the start and decelerated towards the end. This pattern, however, was highly variable depending on the individual and its circumstances. By isolating the initial element from eight selected calls, differences of shape, length, pitch and complexity can be clearly illustrated *(Figure 7)*.

Softer and shorter versions of the call were exchanged between pairs and between adults and young near to, or in the nest tree, with an average of 5 elements (2–9, n=37) and calls of between 3 and 5 elements were heard on consecutive days from a pair 200 m apart, each with juveniles in attendance (Dorset, England. 14/15.08.21). Also, short, harsh versions were given by a bird near a nest with young in reaction to a party of Jays *(Garrulus glandarius)* moving past (Lot, France. 25.05.08).

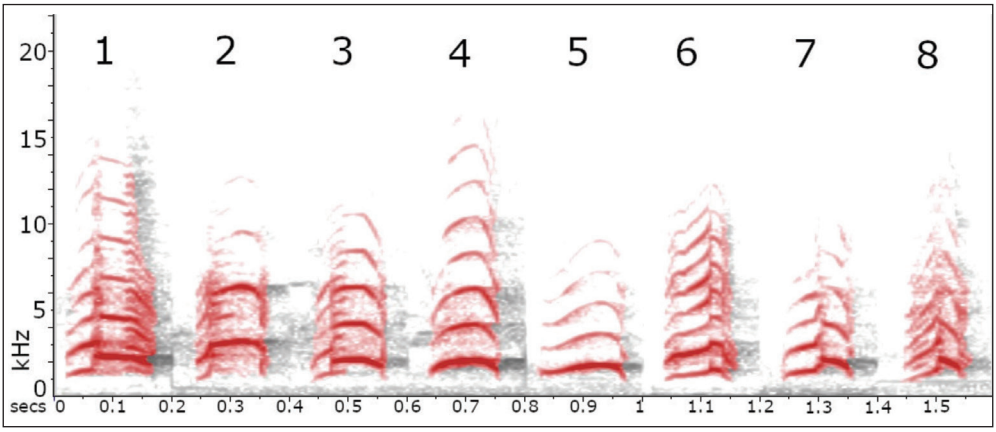

Figure 7. Individual elements (expanded on the x axis) extracted from eight advertising calls given by different birds, showing different fundamental frequencies and some sub-harmonics. (1,2,3,6,8 – Lot, France. 07.04.2013, 01.04.2014, 04.03.2003, 19.03.2005, 26.04.2010, 4 – Dorset, England. 02.02.2007, 5 – Wiltshire, England. 06.05.2008, 7 – Zemplén Hills, Hungary. 14.04.2006)

7. ábra Különböző egyedektől származó vokális hangsorozatok egyes elemei egymás mellé rendezve. (1,2,3,6,8 – Lot, Franciaország. 2013.04.07., 2014.04.01., 2003.03.04., 2005.03.19., 2010.04.26., 4 – Dorset, Anglia. 2007.02.02., 5 – Wiltshire, Anglia. 2008.05.06., 7 – Zemplénihegység, Magyarország. 2006.04.14.)

(b) ***Regular Call Tiew, Kew, Teuk (n=103)***

The most regularly heard call was always composed of repeated elements decelerating through the call and either dropping slightly in pitch from 2.07 to 1.95 kHz (n=30) or remaining flat. Three element shapes were used, from the simple inverted U to slightly more complex and fragmented forms. Unusually, all three shapes (timbres) were given in a single call by a bird arriving to feed young in the nest *(Figure 8)*. In contrast to the advertising call, the stress was always nearer the start of each element.

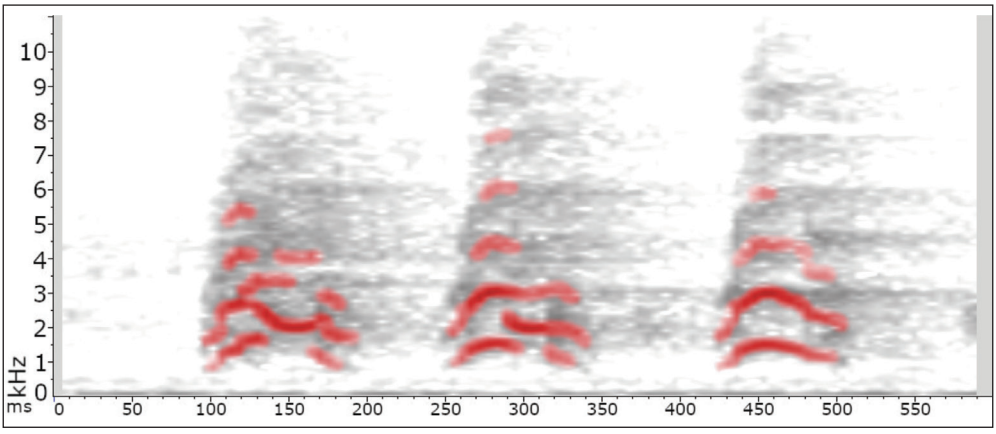

Figure 8. Regular Call *Kew Kew Kew*, three element shapes in a single call. Dorset, England. 12.06.2005.

8. ábra A három elemből álló *„Kew Kew Kew"* hang. Dorset, Anglia. 2005.06.12.

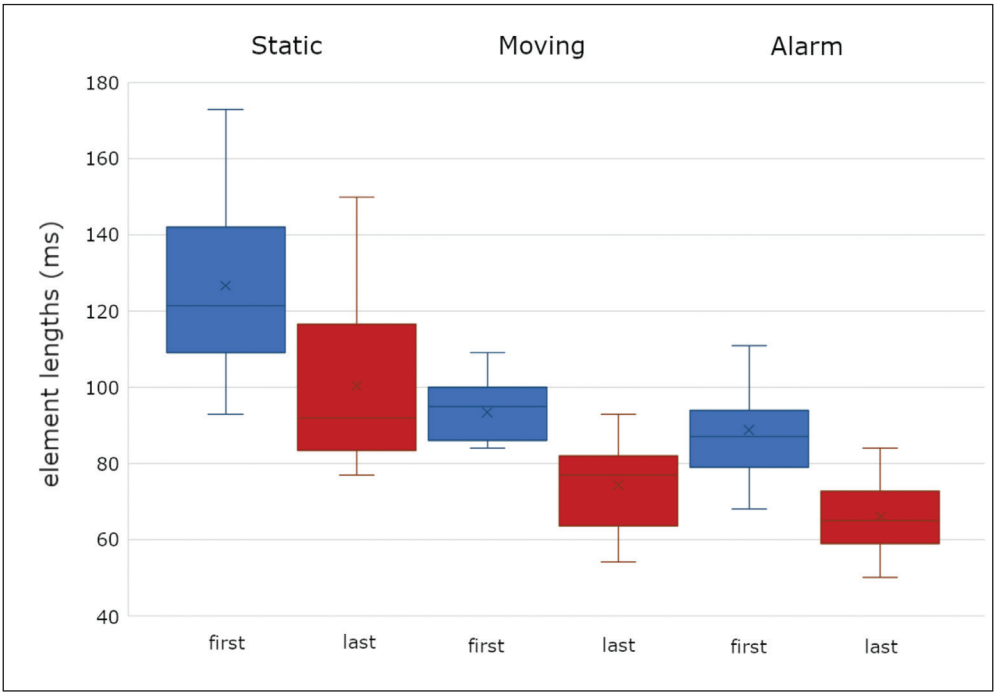

Figure 9. Regular Call: First and last element lengths in milliseconds (blue and red box plots, with median shown as a line and mean shown as X) for the three behavioural contexts

9. ábra „Regular Call": az első és az utolsó elemek hosszának eloszlása három különböző viselkedési helyzetben

The call was associated with three principal behaviours: signalling presence when static, movement (arrival and departure) and alarm near a nest with young. All three element shapes were used in each behavioural context and element lengths consistently reduced through the calls *(Figure 9)*.

Static calls, however, were more frequently composed of longer simple inverted 'U' elements and alarm calls often contained more elements.

(b[1]) ***Static Contact Call (n=18)***

The call, given when close to a nest with young or in answer to a mate, was slow, at 4 or 5 elements per second at an average of 3 (2–5) per call and sounded like stretched and tongued '*Tiews'*. The greater range of element lengths and the overlapping of lengths between first and last elements was only heard during the breeding. Occasionally the first element was slurred into a '*Kiaow'*, almost twice the average length, sounding more like the typical food begging call of juveniles *(Figure 21)*.

(b[2]) ***Movement Call (n=21)***

This call was given by individuals to signal their arrival, following the flight call and also when about to depart. It was faster, delivered at an average of 6 elements per second

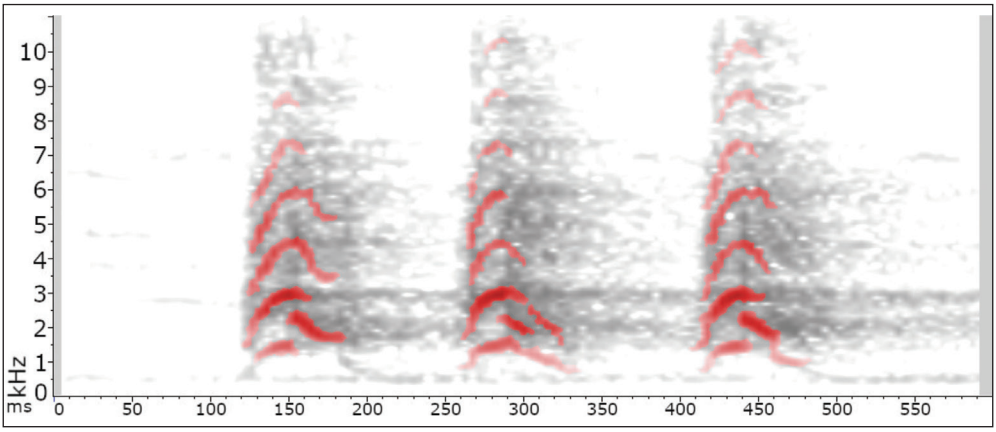

Figure 10. Alarm Call. Dorset, England. 24.06.2001.
10. ábra Három elemből álló „alarm call" (vészhang). Dorset, Anglia. 2001.06.24.

(5–7) and was composed of sharp '*Kews'* or '*Teuks'* at an average of 4.5 (2–7) elements per call *(Figure 8)*. Behaviourally, despite the absence of a potential predator, it may have expressed anxiety when near a nest with young and was structurally close to the alarm call *(Figure 9)*.

(b³) ***Alarm Call (n=64)***
Calls given in alarm near to the nest tree were rapidly repeated in longer series, with thirty or more calls per minute at 6 elements per second. There was an average of 5 elements per call but with a wider range of from 3 *(Figure 10)* to 18. In one example forty-eight calls, ranging from 3 to 6 elements slowing through the sequence, were given over a seven-minute period by a bird disturbed near a nest.

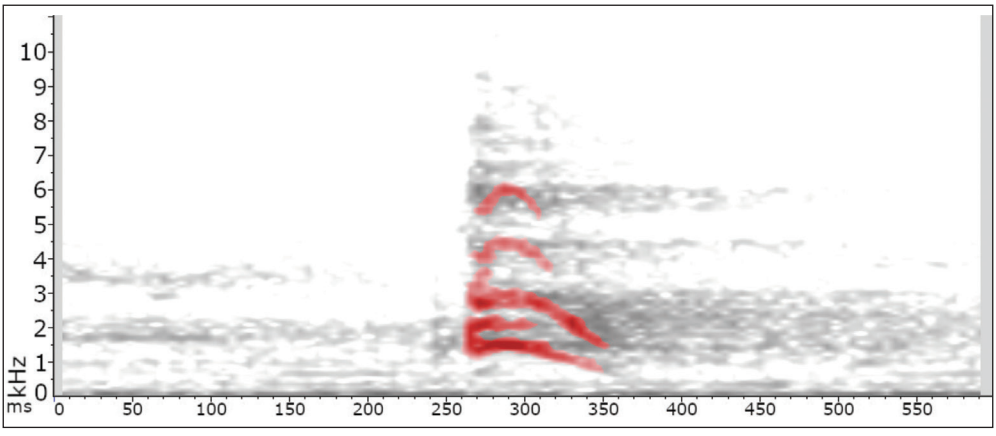

Figure 11. Kuk Call. Bird emerging from roost, responding to its mate's advertising call. Wiltshire, England. 22.01.2006.
11. ábra „Kuk" hang. Az odúból távozás közben, párja hangjára válaszolva. Wiltshire, Anglia. 2006.01.22.

(c) ***Kuk Call (n=3)***

The only single-element call in the Eurasian Green Woodpecker repertoire was the rare '*Kuk'* Call. The best example recorded was short (75 ms) and similar in shape to an element in the *Tiew* call but with a more abrupt start *(Figure 11)* and was lower in pitch (1.48 kHz). No specific functional significance was observed, although in combination with a sharp and higher pitched *'Kik'* element (as in *'Kuk-kik-kuk'*) it was occasionally given by birds when startled in autumn and winter.

(d) ***Flight Call Kjaek, Kjeuk (n=49)***

Flight calls were generally faster than the Regular call, with 7–8 elements per second, slowing on approach to the destination. Calls were higher pitched, dropping from 2.3 to 2.1 kHz through the call when followed at a tangent (n=13). Calls were composed of flat elements, sharp at the start and dropping at the end and were usually short, with an average of 3.2 elements per call (1 to 7). One exceptionally long call of 21 elements was recorded at the start of a sequence. The number of separate calls given in flight varied according to the distance covered, from 1 – between neighbouring trees, to 9 – across a valley (average 3.6, n=14). The call, sounding like repeated *Kjaeks* or *Kjeuks* was given during pair formation and breeding and signalled a change of position within the home-range to the partner or young, especially when approaching the nest when young were about to fledge. It was regularly heard when birds were going to roost and later in the autumn and winter as immature birds were claiming foraging sites. Flight calls associated with disturbance contained changes of pitch between elements *(Figure 12)* and longer, slower, disjointed series (5 elements per second) may have involved more complicated messages.

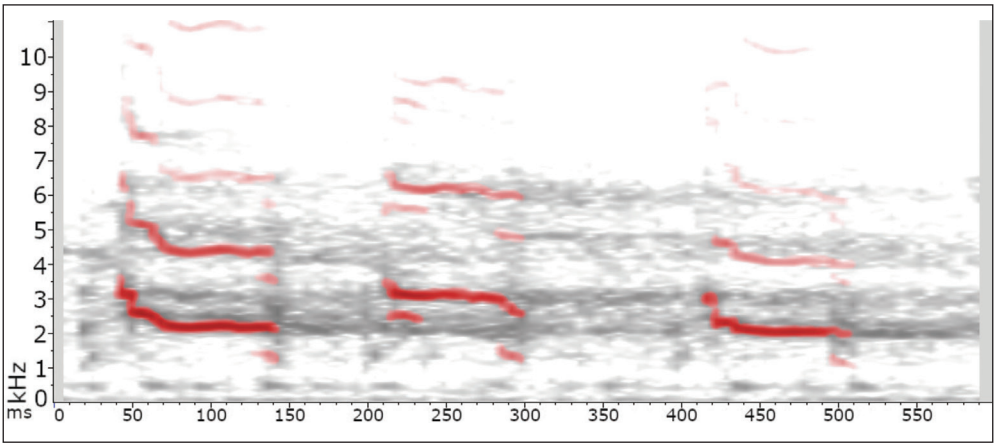

Figure 12. Flight Call, showing a higher pitched second element. The middle of a series of three calls. Lot, France. 29.03.2008.

12. ábra „Flight Call" (repülés közben hallatott hang), melyben a középső elem hangmagassága nagyobb, mint a szélsőké. Hármas hangokból álló hangsorozat egyik közbülső hangja. Lot, Franciaország. 2008.03.29.

(e) ***Alarm Call in Flight (n=1)***
When threatened, usually by an aerial predator, individuals communicated a very real sense of panic, giving loud, modulated *Kju-kju-kjuks* as they fled from danger. In a recording of a bird being chased by a Eurasian Sparrowhawk *(Accipiter nisus)*, a bird gave 18 high-pitched screeches before reverting to a series of fast flight calls (two groups of 5 elements followed by several of 2). The screeched elements, increasing up to 302 ms in length and over 2.8 kHz in pitch, were delivered at 3.5 per second (recorded by K. Barnatt, Lincolnshire, England). The call was most frequently heard in late autumn and may have been given by immature birds being chased out of a home-range. Other threats were observed from Peregrine Falcon *(Falco peregrinus)*, Booted Eagle *(Hieraaetus pennatus)* and Domestic Cat *(Felis catus)*.

(f) ***Autumn Call (n=49)***
This call was heard only for a limited period from approximately four weeks after young had fledged. It was very closely related to the flight call in structure, but given by a bird when static, and contained an average of 9.8 elements per call (4–21), more than twice that of the flight call. Calls were generally sharp and fast, at an average of 7 elements per second (6–9, n=19), decelerating and dropping in pitch from an average of 2.5 to 2.1 kHz (n=12). As with other calls, elements reduced in length as gaps between them increased. From 47 calls (20 from xeno-canto[(2)]) representing at least 17 individuals, 18 were given in two parts – one call followed by another within 3 seconds, with the first generally longer than the second.

(g) ***Threat Call Kjaik (n=11)***
Threat calls were given during close encounters (often with raised crown feathers): during conflict between rivals; by members of a pair when uncomfortable with a perceived invasive presence; and with juveniles when arriving to feed. They were also occasionally given as

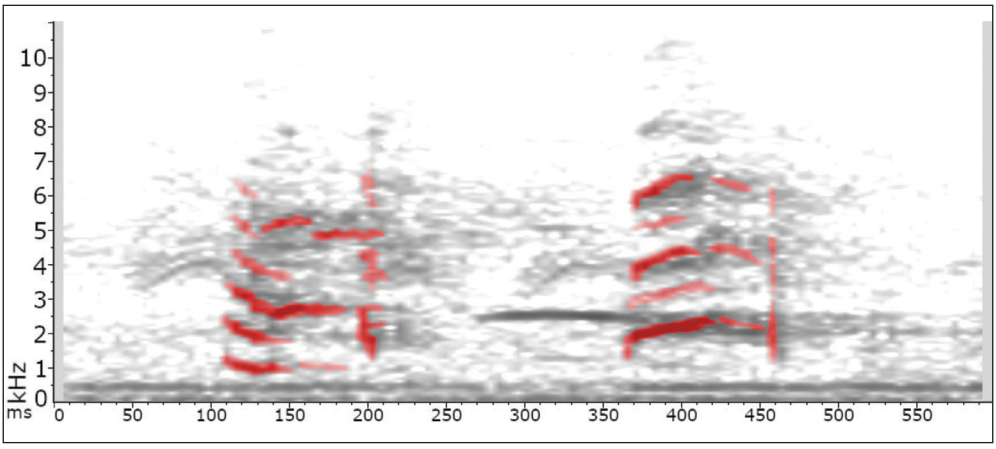

Figure 13. Kjaik Call. First 2 elements from a call containing 34 elements, the first element clearly sharper at the start. Given when in close contact with juveniles. Dorset, England 06.07.2003.
13. ábra „Kjaik" hang. Az első két eleme a 34 elemből álló hangsorozatnak. Fiatalok közelében kiadott hang. Dorset, Anglia. 2003.07.06.

a reaction to the mate's advertising call or during close encounters outside the breeding season. They were not loud and have been aptly described as 'sounding like windows being cleaned with a shammy leather' (Cohen 1946). The call was generally a long repetition of simple, squeaky, *Kjaik* elements (6 to 37) at around 2.5 kHz with the initial element either shorter or irregularly inflected *(Figure 13)*. Element lengths remained consistent throughout the call at about 100 ms and were evenly spaced between 3 to 6 per second over most of the call, although the calls themselves became increasingly widely spaced.

(h) ***Peeuw Call (n=10)***

The *Peeuw (Piu, Pweep)* calls were very soft, thin, intimate signals given during courtship and when a pair met at the nest hole, or a bird arrived to feed young. They were typically delivered in a series of up to 19 long *'Peeuw'* elements from 2 to 3.5 per second and were relatively pure in tone. The average element length was 230 ms (133–355) more than twice that found in any other call (n=53). In the four measurable examples, the average pitch was 2.1 kHz. After a sequence of soft drumming and advertising calls given at dawn, a bird called with 12 regularly spaced elements in response to its mate's soft drum-rolls on arrival in the same tree – recalling the courtship and mating sequences of Grey-headed Woodpecker *(Picus canus)*. '*Peeuw*' calls were also given by pairs in a duet. In one example, the nearer bird gave five calls (14, 19, 5 and 10 elements) which occasionally coincided with the second bird's calls *(Figure 14)*. Only one instance of this call-type was heard outside the breeding season.

Variations of this call included a sharper '*Tche*' at the start of each element and an apparent separation from the '*uw*' at the end, sometimes shortened to a '*T – we' (Figure 15a)*. Occasionally these sub-elements or variations on them were given individually.

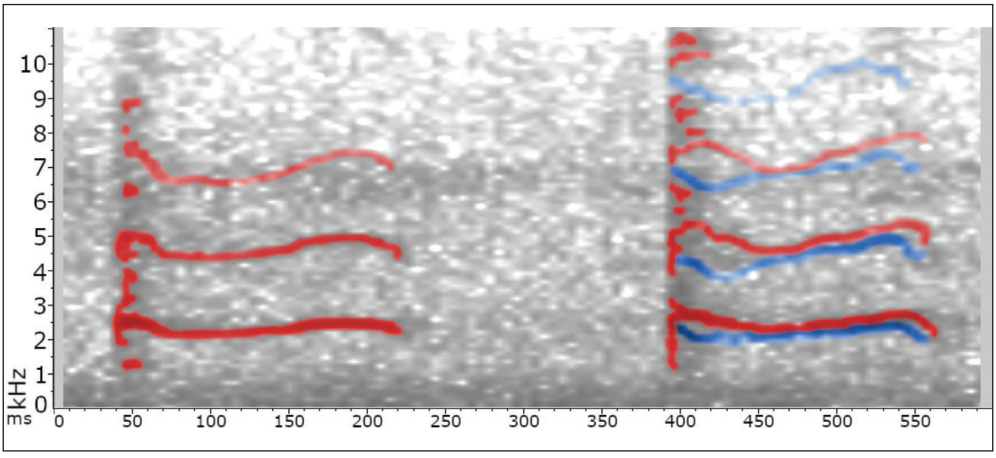

Figure 14. Peeuw call. Pair at the nest hole (containing small nestlings). The second element of the first bird's call (coloured red) is precisely matched by the second bird (coloured blue). Lot, France. 12.05.2008.

14. ábra „Peeuw" hang. Egy pár által a fiókás fészek közelében kiadott hang. Az egyik egyed által kiadott hang (piros) második eleme átfed a másik egyed hangjával (kék). Lot, Franciaország. 2008.05.12.

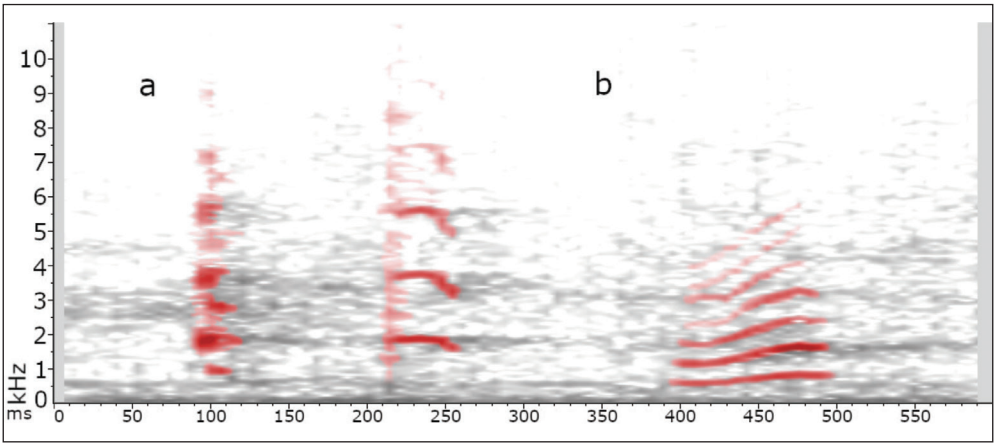

Figure 15. (a) A '*T – we*' variant of the '*Peeuw*' call element and (b) – a separate '*Wa*' given at the nest as the mate came close (300 ms have been cut from between the calls for easier comparison with previous spectrograms). Lot, France. 25.05.2008.

15. ábra A fészek közelében hallatott hangok, (a) „t – we" variánsa a „Peeuw" hangelemnek és (b) „Wa" hang. 300 ms szünet volt kivágva a két hang közül. Lot, Franciaország. 2008.05.25.

(i) ***Wa Call (n=1)***

Other extremely faint sounds were made by adults close to nest holes, such as the rising '*Wa*' element (101 ms, ff 0.8 kHz) *(Figure 15b)* which followed a sequence of '*T – we's*.

(j) ***Squeak Call (n=1)***

An example of a thin and rapid '*We-we-we*' call, with a sibilant quality similar to *Picus sharpei*, was given by an unmated bird during a series of advertising calls and after a soft drum-roll. Elements shortened from 71 to 42 ms and increased in pitch from 2.47 to 2.64 kHz while the tempo slowed *(Figure 16)*.

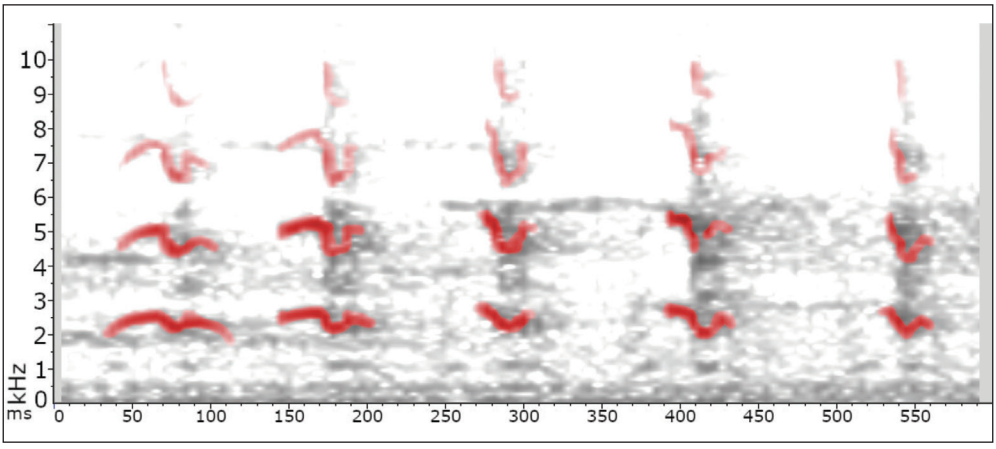

Figure 16. Squeak call. Dorset, England. 02.05.2021.

16. ábra „Squeak" (vinnyogó) hang. Dorset, Anglia. 2021.05.02.

Calls of nestlings and juveniles

During the first week after hatching, nestlings produced long series of continuous, low, rasping noises *(Figure 17)*. These gradually became separated into short, grating elements, sounding like tearing cardboard and were given when an adult was heard near the nest *(Figure 18)*. Before fledging, purer elements were added *(Figure 19)*.

The combination of harsh, grating calls and purer, more '*Kew*'-like elements gave way to sharp, squeakier sounds repeated in long series at the point of fledging. They were mostly given singly at, on average, one every three seconds, accelerating as an adult arrived, but were also repeated in groups of up to six elements at 5 per second and at 2.86 kHz (n=17). The sharpest element was usually at the start *(Figure 20)*. At about 80 ms in length, they were shorter than the

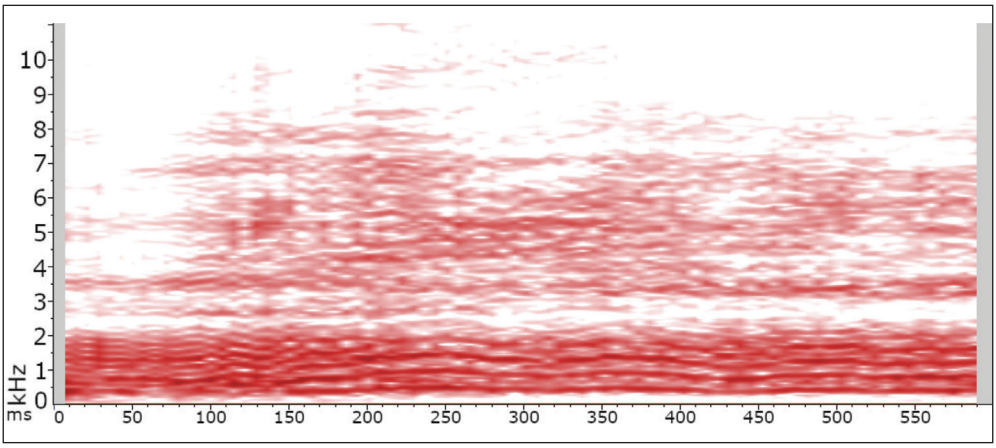

Figure 17. Calls of nestling during the first week after hatching. Lot, France. 13.05.2011.
17. ábra Fiókák hangja a tojásból kibújás utáni első héten. Lot, Franciaország. 2011.05.13.

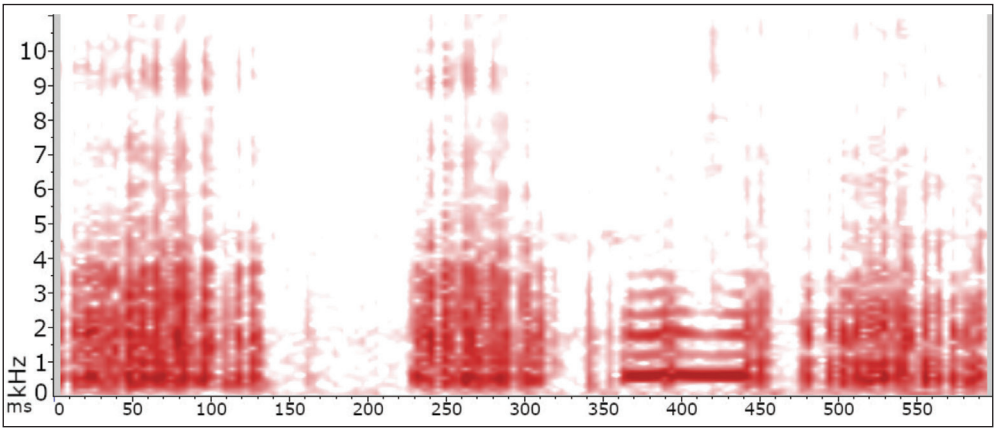

Figure 18. Nestlings making a ripping, tearing sound in very short (8 to 12 ms) staccato elements, with an occasional soft note (at 360 ms). Lot, France. 13.05.2011.
18. ábra Fiókák különböző zörejszerű hangjai és egy lágy, szabályosabb zönge jellegű hangja (360 ms-nál). Lot, Franciaország. 2011.05.13.

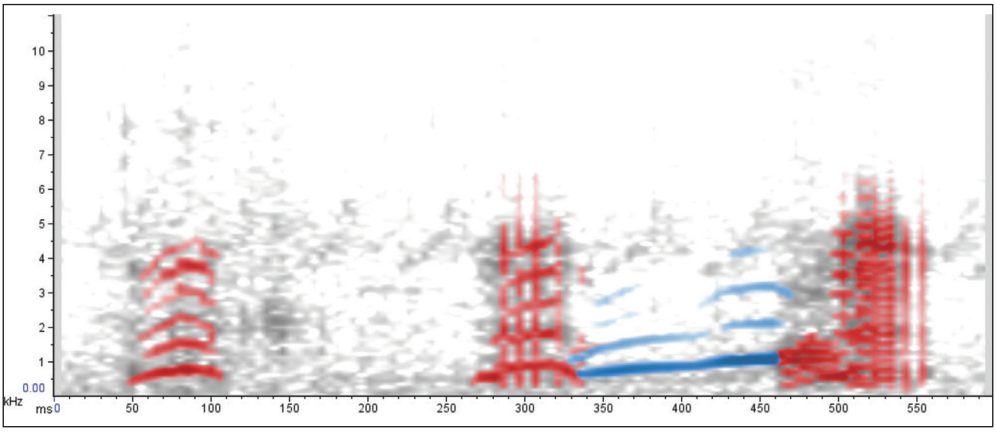

Figure 19. Nestling at approximately 2 ½ weeks, showing a similar shape to an adult call in the first element but sounding more like a squeaky rubber duck, plus two grating transitional elements. A second nestling gives a purer, rising note (coloured blue). Lot, France. 21.05.2011.

19. ábra Fiókák hangja két és fél hetesen. A felnőttekére jobban hasonlító átmeneti jellegű hangok az egyik egyedtől (piros). Egy tisztább, emelkedő hang egy másik fiókától (kék). Lot, Franciaország. 2011.05.21.

lower pitched food calls which soon replaced them. In these calls, which typically consisted of two or three elements (1–7, n=33), the first element was slightly longer (120 ms), higher pitched and more emphasised, with subsequent elements usually descending in pitch *(Figure 21)*. Both calls typically had a longer interval between the first and second elements. A quieter, non-vocal variant (presumably produced by the tongue but sometimes ending in a squeak) sounded more like *'T-lew'*. Juveniles approaching independence often retained a longer, slightly modulated element at the start of an otherwise typical adult's '*Kew Kew Kew*' call.

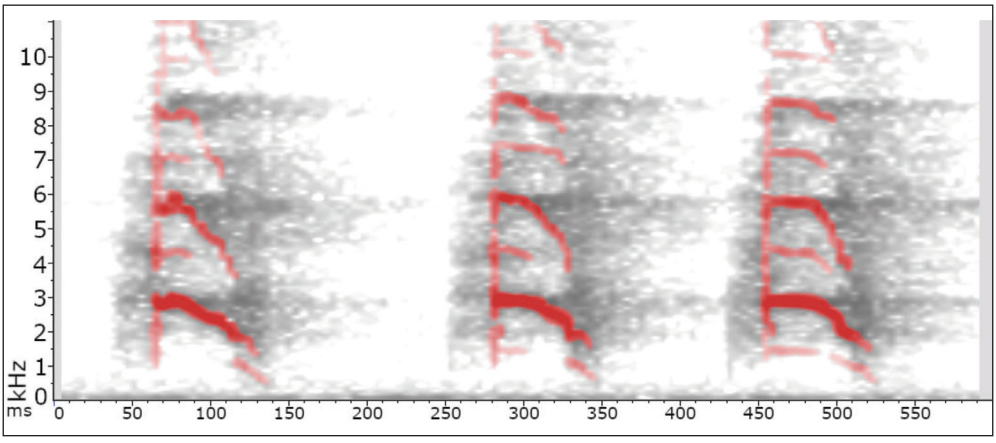

Figure 20. Juvenile giving a sharp, high-pitched call immediately on leaving the nest. Dorset, England. 19.06.2005.

20. ábra Egy fiataltól származó éles, magas hang a fészekelhagyás közben. Dorset, Anglia. 2005.06.19.

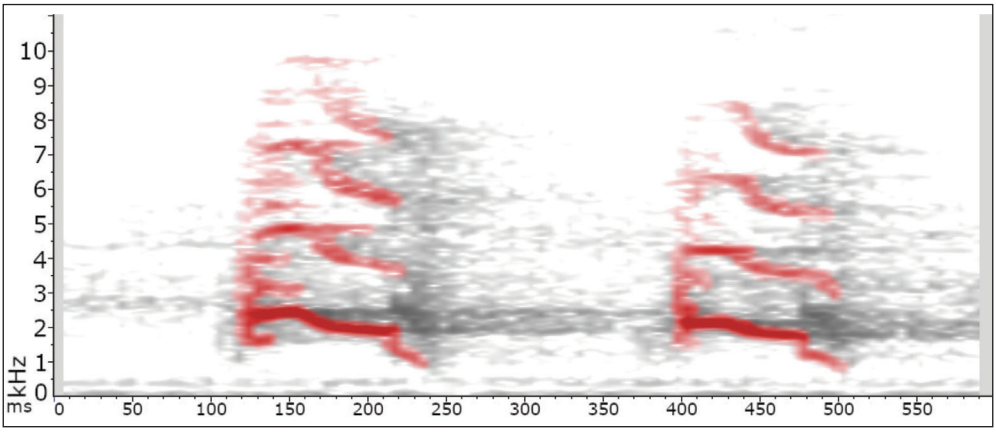

Figure 21. Food call of a juvenile a few days after fledging, showing a longer and more emphasised first element and a drop in pitch to the second of 0.4 kHz. Lot, France. 30.05.2019.

21. ábra Fiatal madár táplálékkéregető hangja néhány nappal a kirepülés után. Hosszabb és erősebb első hang. Lot, Franciaország. 2019.05.30.

Discussion

The absence of loud, rhythmically stable drumming in the Eurasian Green Woodpecker constitutes a behavioural separation from most other European Picinae (Turner 2020). Typical woodpeckers drum on acoustically resonant branches or trunks around a potential nesting site, maintaining regular, species-specific patterns which are either largely uniform or accelerate through the roll (Zabka 1980, Florentin *et al.* 2016). This produces a very effective, far-carrying, advertisement of suitability to a prospective mate while also discouraging rivals (Winkler & Short 1978). The Eurasian Green Woodpecker, however, has evolved to forage terrestrially, in open woodland/grassland habitats, and thus its loud advertising calls, given from isolated trees or clumps, serve better to bring breeding pairs together. In our study, we found that all examples of drumming were extremely weak and irregular *(Figure 2)*, lacking any repeatable structure in the amplitude of the strikes throughout a roll *(Table 1)*. This, together with its predominant use when pairs were close, suggests that it has become a component of courtship once a potential nesting site has been identified. Isolated rolls heard during excavation, or a series of advertising calls appeared to be instinctive reactions to the breeding urge, since they could not have been audible to a second bird. A similar result was found with the rarely heard tap/drumming of Middle Spotted Woodpecker which was thought to have adapted its loud advertising call as a result of the competition of drumming from other, stronger-billed, woodpeckers sharing the same habitats (Turner 2020). A rare example of louder drumming was heard from a Eurasian Green Woodpecker drumming on metal plates surrounding the entrance holes of at least two nest-boxes. Drumming was amplified and could be heard over a hundred metres away (Kramer 2009). The patterns of drumming and tapping described in that account, however, were matched by the extremely soft versions recorded during the present study and none of the authors, in many hours of observations, has encountered such far-carrying examples.

As with the sexual differences apparent amongst woodpeckers that drum territorially (Blume & Tiefenbach 1997), an advertising call used also for pair bonding would only be effective if males and females were able to identify each other (Węgrzyn *et al.* 2021). There are, indeed, some possible indications of sexual difference in advertising calls. For example, an analysis by H. H. Bergmann of a recording by K. Hinrichs showed strong harmonics and monosyllabic fundamentals in a female's advertising call, in contrast to the male's disyllabic fundamentals (Cramp 1985). We found that in confirmed examples of advertising calls given by females (n=7 from 4 birds), the first element was softer and lower pitched and subsequent elements remained fairly evenly pitched, in contrast to confirmed male calls. However, in a pair recorded between April and June 2022, the female's advertising calls were longer (9 elements compared to 7.5 on average) and faster (7.4 elements per second compared to 6.1) with short final elements (female n=29, male n=15). They were also 0.3 kHz higher in the overall frequency of the first element (2.3 kHz compared to 2.0 kHz) and did not decelerate. Once these differences were identified, the birds were easy to tell apart by ear. These are small samples, and any overall rule must remain speculative until a full study of positively gender-identified recordings can be obtained. We did not attempt a statistical comparison of call characteristics between our two principal study areas (France and England). Variation was far greater within each area than between them. There is likely to be considerable value from increasing the number of available acoustic recordings of woodpecker species from across their ranges in developing methods for species and individual recognition algorithms (Florentin & Verlinden 2017, Stowell *et al.* 2019, Vidaña-Vila *et al.* 2020).

An interesting change in the seasonal use of the advertising call and hence the breeding cycle is indicated by comparing our finding of a March to May peak with a survey from 1961 which showed the greatest intensity from February to April (Blume 1962). One possible explanation for this might be a later availability of ants during a period of rising global temperatures, possibly explained by levels of rainfall and grass length (Cramp 1985) but this warrants further study. Juveniles were still being fed in the middle of August in the UK in 2021. However, if we have correctly identified what has been referred to as the 'autumn call', the majority of the 49 examples that we found were heard in summer – 10 in the second half of July, 33 in August and only 6 in September, although the call was still occasionally heard towards the end of September 2022. The call appeared to be associated with the move by juveniles towards independence, indicating increased excitement or antagonism and may be exclusive to them. In our study, there was a clear structural similarity to the flight call, with which it was sometimes combined, rather than the advertising call (Cramp 1985).

Variations in what we refer to as the 'Regular Call' within individuals appear to indicate different meanings. An in-depth behavioral study of several individual's repertoires would be needed to establish the degree to which the variables in element structure relate to their function or to the birds as individuals. Irregular forms of tapping described as 'excitement pecking' (Blume & Jung 1958) were heard during this study but we do not consider them to have constituted ritualised signals.

Conclusion

In our study, we found that the instrumental signals, including drumming, of Eurasian Green Woodpecker were always very soft and were used predominately in the vicinity of nests during courtship interactions. No evidence was found for the use of drumming as a territorial signal. The repertoire of vocal signals consisted almost entirely of calls containing simple, repeated elements with stress typically given on the first element and a gradual deceleration thereafter. In all but three calls, modulation within elements involved a rise and fall of pitch – the typical shape shown in spectrograms of other European woodpecker calls (Winkler & Short 1978, Blume 1996). In the advertising call, the peak appeared before the middle of the element, in contrast to other loud calls where it came after. While there was an overall tendency toward deceleration and reduction in element lengths, familiarization with the combination of differences in; element shape, call duration and speed, appeared to provide an effective way to separate individuals. Differences in element lengths found in the Regular call also indicated a range of meanings related to movement and alarm. Motivation also affected call characteristics, in particular, a higher pitched second, or alternating element indicated disturbance. We found the peak of advertising calls to be from March to May, a month later than a survey conducted in 1961 (Blume 1962).

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