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The number of syllables in Chernobyl cuckoo calls reliably indicate habitat, soil and radiation levels

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ABSTRACT

Cuckoos *Cuculus canorus* produce calls that consist of a repeated but variable number of syllables that has given name to the species and the family. Here we tested the hypothesis that cuckoo calls are reliable indicators of environmental and individual quality by determining the number of repeated 'cuckoo' syllables in calls in relation to habitat and soil, ionizing radiation, presence of a female cuckoo and local density of male cuckoos at Chernobyl, Ukraine. Males were consistent in their production of syllables, producing more syllables per call when a female or another male arrived. This increase in the number of syllables was larger in males that already produced many syllables in the absence of conspecifics, implying that males of superior quality were still able to increase the number of syllables. Males produced more syllables per call in habitats with black soil and in forests. Furthermore, they produced fewer and more aberrant syllables in radioactively contaminated areas of Chernobyl providing evidence of an effect of environmental perturbation on the number of syllables. These findings are consistent with the hypothesis that the number of syllables is a condition-dependent signal used for attracting mates, repelling competitors, providing information about local environmental conditions for other cuckoos, but also for humans and thus can be used by humans to infer habitat quality.

1. Introduction

Parasitic cuckoos are highly vocal with their calls having given rise to their name across numerous languages (Davies, 2015). Yet there are hardly any studies of the function of their cuckoo calls. Why should cuckoos produce so many and such loud calls, and what do these calls signal to conspecifics and heterospecifics including humans? Cuckoos are renowned for their obligate parasitic behavior, relying on hosts for rearing their offspring (Wyllie, 1981; Davies, 2000, 2015; Payne, 2005). Cuckoos have recently been shown to be reliable indicators of biodiversity because their presence mirrors the species richness of their hosts and hence the overall bird community (Morelli et al., 2015; Tryjanowski and Morelli, 2015).

Given that the Web of Knowledge had no less than 2181 publications on cuckoos on 31 July 2015 there is a surprising lack of published information on the calls that have given name to the species and this bird family. Cuckoos are non-passerines that do not learn calls, but presumably have calls that are affected by inherent genetic factors (Marler and Slabbekoorn, 2004). Hence, the expression of calls should be affected by mutations. Three studies have investigated variation in spectral and temporal properties of cuckoo calls. Fuisz and de Kort (2007) showed that call structures differed significantly among male cuckoos occupying different types of habitats. This observation combined with habitat imprinting could provide a mechanism for maintenance of host specific cuckoo races. Furthermore, Jung et al. (2014) showed that male cuckoos differed individually in the structure of their calls. Finally, Wei et al. (2015) showed that the structure of the different components of the cuckoo call differed geographically and among subspecies.

The function of cuckoo calls is only poorly known. Cramp and Perrins (1986) termed the repeated cu-cooo syllable of this vocalization an advertisement call. Typically, a cuckoo call consists of a sequence of repeated cu-coo sounds (each considered a syllable here) ending with a pause of a few seconds, the equivalent of more than the duration of one syllable, which separates two different series of syllables. Up to 300 syllables have been reported in a sequence. More rapid calls are given when a male is excited with a maximum of 26 syllables per 30 s (Bögershausen, 1976)

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delivered from a perch or rarely in flight. Calls are given during day, but also at night (Löhrl, 1950). Calls are produced throughout the breeding season, but at the beginning and the end calls are hoarse. Wyllie (1981) reported variation in the seasonal frequency of calling although no details were reported. Calls are given much less frequently in cold and thundery weather than when it is sunny (Groebbels, 1957; Melde, 1982).

Given the time and the effort used by cuckoos to produce hundreds of calls daily, and given that calls can be heard at a distance of 2–3 km in calm weather depending on the habitat, this suggests that cuckoo calls have an important signaling function. The number of syllables produced by individual males in the hoopoe *Upupa epops* (Martín-Vivaldi et al., 1998) and several passerines (Catchpole and Slater, 2008) are also consistent over time, suggesting a signaling function of call length. Previous studies have shown that this call attribute predicts mating and reproductive success in terms of extra-pair offspring in these species (Martín-Vivaldi et al., 1999, 2002; Catchpole and Slater, 2008). This raises the possibility that similar mechanisms may be involved in vocal communication in cuckoos as in other species of birds.

Cuckoos are unlikely to be distributed randomly because individual condition (and therefore call length) will be linked to habitat quality and thus soil type. Soil may in turn affect plant cover and hence availability of insect food such as the abundance of caterpillar larvae that constitute the main source of nutrition for cuckoos. Since larvae are located near the top of the soil, where most radionuclides are located, we might expect fewer caterpillars and hence fewer butterflies in areas with higher background radiation level (Møller and Mousseau, 2009). Thus, there should be a reduction in food abundance in more contaminated areas. These arguments suggest why the number of syllables in a cuckoo call is a reliable indicator of environmental conditions.

The objectives of this study were to assess the use of cuckoo calls as indicators of environmental conditions. Specifically, we tested (1) whether the number of syllables was repeatable among calls of an individual cuckoo; (2) whether more syllables were produced in the presence of more conspecific males and females, and whether this increase in the number of syllables with the appearance of a conspecific male or female was larger for males that initially had many syllables. Such an increase in the number of syllables in males with initially many syllables is predicted by the handicap principle and condition-dependent signaling. According to that hypothesis signallers with an initially high level of signaling are also those that are differentially able to signal at a higher level when challenged by a conspecific male or female (Zahavi, 1975; Johnstone, 1995); and (3) whether the number of syllables was a reliable indicator of environmental conditions as reflected by soil (clay, sand or black soil), habitat (forest or agricultural habitats) and radioactive contamination. We hypothesize that higher quality soils and more diverse habitats would hold more caterpillars that are the preferred diet of the cuckoo (Cramp and Perrins, 1986) and therefore would hold cuckoos in better condition. We test explicitly whether the abundance of butterflies varies among soil types differing in abundance of cuckoos.

2. Methods

2.1. Study sites

APM studied cuckoos in Ukraine in forested areas of a total of 2000 km^2 in the Chernobyl Exclusion Zone and outside this area ranging from Bobor, Dytiatki and Pisky to Ivankov with a small control area around Voronkov. This study lasted 27 May – 10 June 2015 and was part of an extensive bird census program consisting of point counts covering a total of 250 census points each lasting 5 min (see Møller et al. (2015) for further details). APM and TAM also recorded cuckoos with aberrant call that deviated from ordinary cuckoo syllables during extensive fieldwork in the Chernobyl Exclusion Zone 1991–2014.

2.2. Recording the number of syllables

We recorded the number of syllables (each syllable being a single cu-coo) that a cuckoo male produced in a single call by waiting for a call to be finished in order to avoid inclusion of calls that were initiated before arrival of the observer. Once the male started to sing again, we recorded the number of syllables in the next two calls, if possible (some males left before a second call was initiated). This allowed for repeatability analysis of the number of syllables per call based on the second and the third call. A call was considered to be finished when at least a period of time similar to that of a syllable had passed without a new syllable being produced.

If a female arrived, as judged from the typical female call (Cramp and Perrins, 1986), or a female with the typical brown morph, we recorded the number of syllables in the presence of the female and the number in the previous call in the absence of a female. This allowed us to record the effect of female presence on the number of syllables. We also recorded the number of males present at the same time as the focal male was investigated for the number of syllables. This allowed us to estimate how the number of syllables depended on the number of male competitors present at a single site.

When the number of syllables was recorded, we also noted date, time of day, temperature (measured with a thermometer to the nearest °C), wind (on the Beaufort scale from 0 to 12), cloud cover (estimated in eighths of the sky covered with clouds), and precipitation (either rain or no rain). There were no clear effects of weather conditions, and these variables were thus excluded from subsequent analyses. Finally, we recorded whether the cuckoo was located in agricultural habitats (meadows) or forest. Furthermore, we recorded whether the soil was sand or black soil. We took great care not to include the same male more than once, moving at least a distance of 500 m before making a subsequent record of the number of syllables in a call. This distance is consistent with distances between neighboring male cuckoos as recorded in studies based on radio-telemetry (Wyllie, 1981).

2.3. Cuckoo hosts

In Ukraine common cuckoo hosts include the great reed warbler *Acrocephalus arundinaceus* (89 out of 390 cuckoo eggs) and the marsh warbler *Acrocephalus palustris* (65 out of 390 eggs), white wagtail *Motacilla alba* (35 out of 390 eggs), red-backed shrike *Lanius collurio* (31 out of 390 eggs) and robin *Erithacus rubecula* (20 out of 390 eggs; APM unpublished records).

2.4. Background radiation

Breeding birds generally remain within their territory during the breeding season (Cramp and Perrins, 1988–1994), and this implies that all individual birds remain at the site once chosen for reproduction with little heterogeneity in background radiation during the breeding season. We measured radiation levels in the field at all the survey points, and the radiation level at the actual census point provides information about the radiation level experienced by any individuals during breeding due to the sedentary habits of breeding birds. We measured α, β and γ radiation at ground level at each survey point after having conducted the survey (thus making the survey blindly with respect to radiation level) using a hand-held dosimeter (Model: Inspector, SE International, Inc., Summertown, TN, USA). We measured levels several (2–3) times