

The acoustic structure and possible mechanical origin of the male Corncrake call

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Abstract

The male Corncrake *Crex crex* produces a distinctive repetitive call whose acoustic structure suggests a mechanically constrained sound-production system rather than a conventional tonal vocalisation. Here I describe observations obtained from approximately 800 field recordings made on Skye between 2020 and 2026 and develop a testable hypothesis for the origin of the long-duration and repetitive acoustic structure of the call. A provisional mechanism is proposed in which rapid closure and opening of alternate syrinx lumens, by a self-oscillating part of the syrinx, generate transient vibration of the tympaniform membranes, with the interclavicular air sac and suprasyringeal vocal tract contributing to resonance and radiation. The mechanism is compared conceptually with the echolocating click-production mechanism described for the Australian Grey Swiftlet. The present study is hypothesis-generating and does not include direct anatomical observations required to establish the proposed mechanism.

Keywords: Corncrake; *Crex crex*; syrinx closure; tympaniform membrane; click; bird sound production

Introduction

The Corncrake *Crex crex* is notable for its repetitive, harsh call, conventionally represented as a sequence of closely repeated (6-12 ms spacing), loud broadband pulses (2-7 kHz) making a syllable. The call is about one second long and is made up of two syllables. It can continue for several hours without any rest.

The field observations underlying this manuscript suggest that higher-quality recordings often contain a double-pulse structure in which two closely spaced components occur at the start of an individual pulse with an interval of approximately 1 ms.

A potentially relevant comparative model is the echolocating click of the Australian Grey Swiftlet, for which Suthers & Hector (1982) established a mechanism involving rapid events at the syrinx and vibration of associated membranes. The present study does not assume homology between the two systems; rather, it uses the swiftlet mechanism as a conceptual framework.

The aim of this study is therefore to develop a mechanistic hypothesis linking syrinx structure to sound production derived from observations of waveforms.

Materials and Methods

Study material

The study material comprises field recordings of male Corncrakes made to track movements on the Isle of Skye during 2020–2026. Most recordings were done using mobile phones which were found to be able to present sufficient quality to emulate the original description of the fine structure the call. (Peake *et al.* 1998, Arnold 2025). They were used as 16-bit WAV files at 44.1 kHz sampling rate and analysed using Raven Lite (Cornell Lab of Ornithology).

Table 1. Total number of recordings and total number of birds.

Year	Recordings analysed	Birds identified
2020	80	11
2021	70	13
2022	113	14
2023	95	18
2024	139	28
2025	130	30
2026	162	28
Totals	789	142

Acoustic measurements

The analysis used waveform amplitude charts. For each call, 10 pulse-to-pulse durations (PPD) were extracted by visual examination of waveform displays as described in Arnold (2025). In high quality recordings there was often a distinct double pulse at the start of each pulse with a separation of about 1 ms which is key to the current study.

Quality control

Recordings were band-pass filtered in Raven Lite (Cornell Lab of Ornithology) from 600 Hz to 10 kHz to reduce wind noise and were assigned a quality figure according to pulse clarity and signal-to-noise ratio (Arnold 2025).

Mechanistic hypothesis

The proposed acoustic structure raises a mechanistic question: how can the avian sound-production system generate two sharply defined events separated by an interval of approximately a millisecond?

The working hypothesis is that the double pulse arises from rapid closing and then opening of the syrinx exciting the tympaniform membranes, in a similar way to the Australian Grey Swiftlet (Suthers & Hector 1982). The closing and opening of the lumen generates the broadband (2-7 KHz) loud noise that is observed in the Corncrake call which would otherwise be a more muted squawk.

The interclavicular air sac surrounding the syrinx provide acoustic amplification, while the trachea and pharynx could shape and radiate the resulting sound as described by Ruppell. (Ruppell 1933).

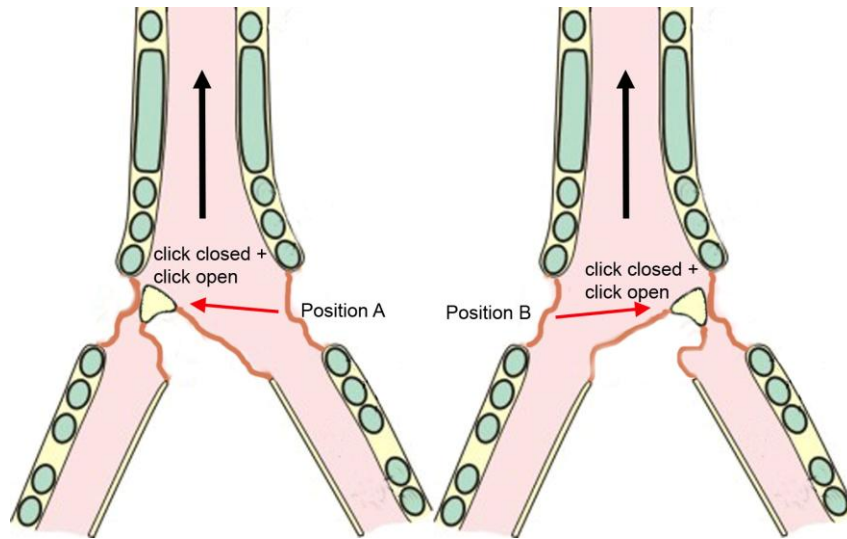
Suthers' work on Oilbirds and Australian Grey Swiftlets (Suthers & Hector 1982, Suthers 2001) describes what he calls 'minibreaths' which are a short inhalation between exhaled syllables. Bird respiration is not

tidal with compressible lungs as in mammals but their incompressible lungs have a constant airflow in one direction derived from the arrangement of air sacs in both ends of the body, driven by the muscular control of their hinged rib cage. This is how the Corncrake is able to call continuously for hours without needing a rest. There is no deficit of air or accumulation of stagnant air in the lungs.

My further suggestion is that effective closure and opening alternates between the two arms of the syrinx (represented as A-B-A-B-A-B etc. (Figure 1)), with the mechanical properties of a self-oscillating structure playing a substantial role. This sequence is not presented as an established anatomical description of the Corncrake. I have not found any anatomical description of the syrinx of the Corncrake.

The spacing of the syllables into calls is under the control of the bird and can indicate mood but the syllables have the fixed PPD pattern that the bird cannot alter. Osiejuk describes what he calls RHYTHM to illustrate this. (Osiejuk *et al.* 2004).

Figure 1. A mechanical movement (6-12 ms pulse duration) across from position A to B and back by some self-oscillating part of the syrinx. The length of time taken for each movement is dependent on individual anatomical properties. It is resonance, like a rattling, and is therefore stable for the life of the bird. The observed 1 ms double click occurs as the lumen of the syrinx is closed and then immediately opened. The clicks are the source of the loud volume and sharp rise time of the waveform which give the call its long range.



Results

Double pulse or click observation

Inspection of waveforms in clear recordings indicated that there are often two peaks at the start of a pulse separated by about 1 ms. The waveform provides useful information about pulse structure without relying on spectrograms. To provide a context the whole call structure is displayed below (Figure 2) (Arnold 2025). It shows what PPD (pulse to pulse duration) means.

Figure 2. **a)** Two calls made up of two syllables each. 2.5 seconds long. Waveform below the spectrogram. **b)** One syllable expanded. 0.15 seconds (150 ms) long. Waveform below the spectrogram. **c)** Three pulses expanded. 0.02 seconds (20 ms) long. Waveform only. PPD 1 and 2 are marked.

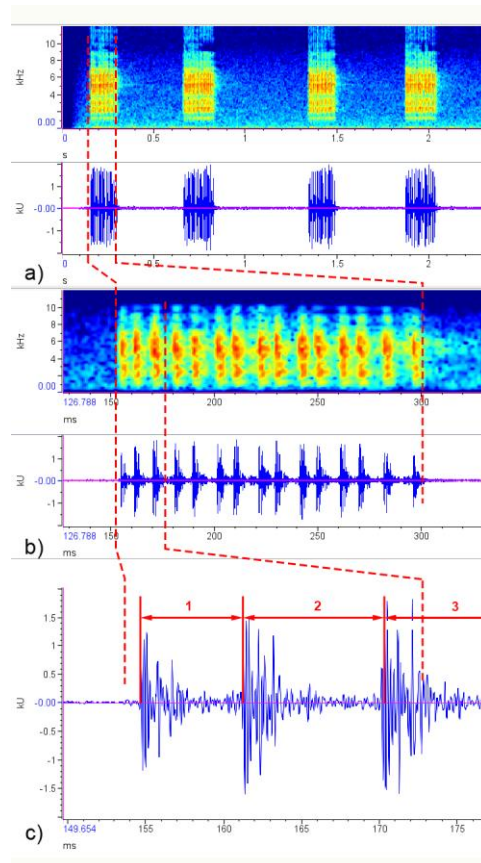


Figure 3. An example of a good quality recording showing 4 pulses with the initial 1 ms double pulse start which suggests the closing and opening the syringe lumen.

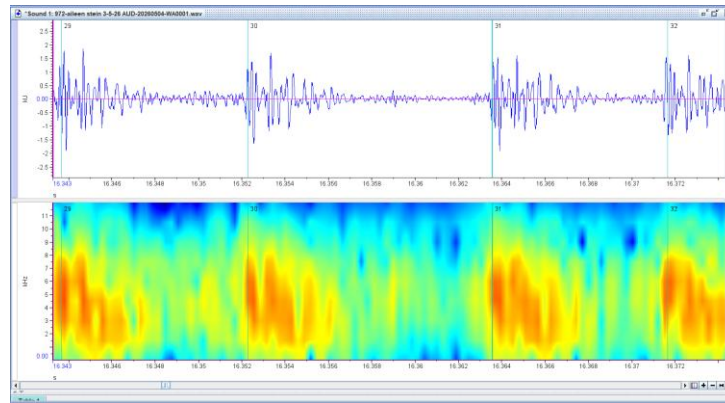
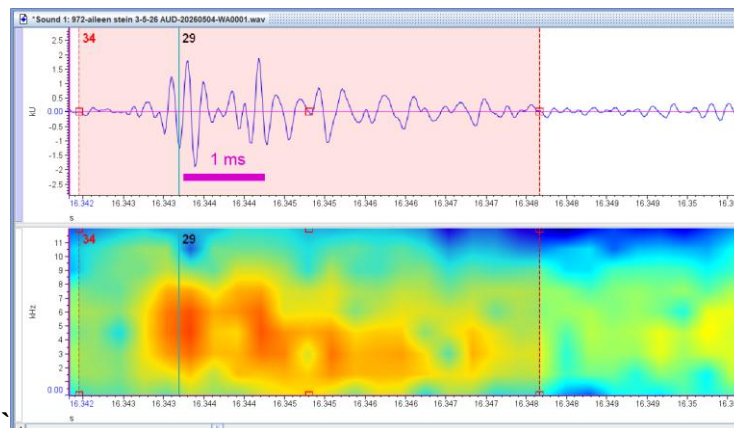


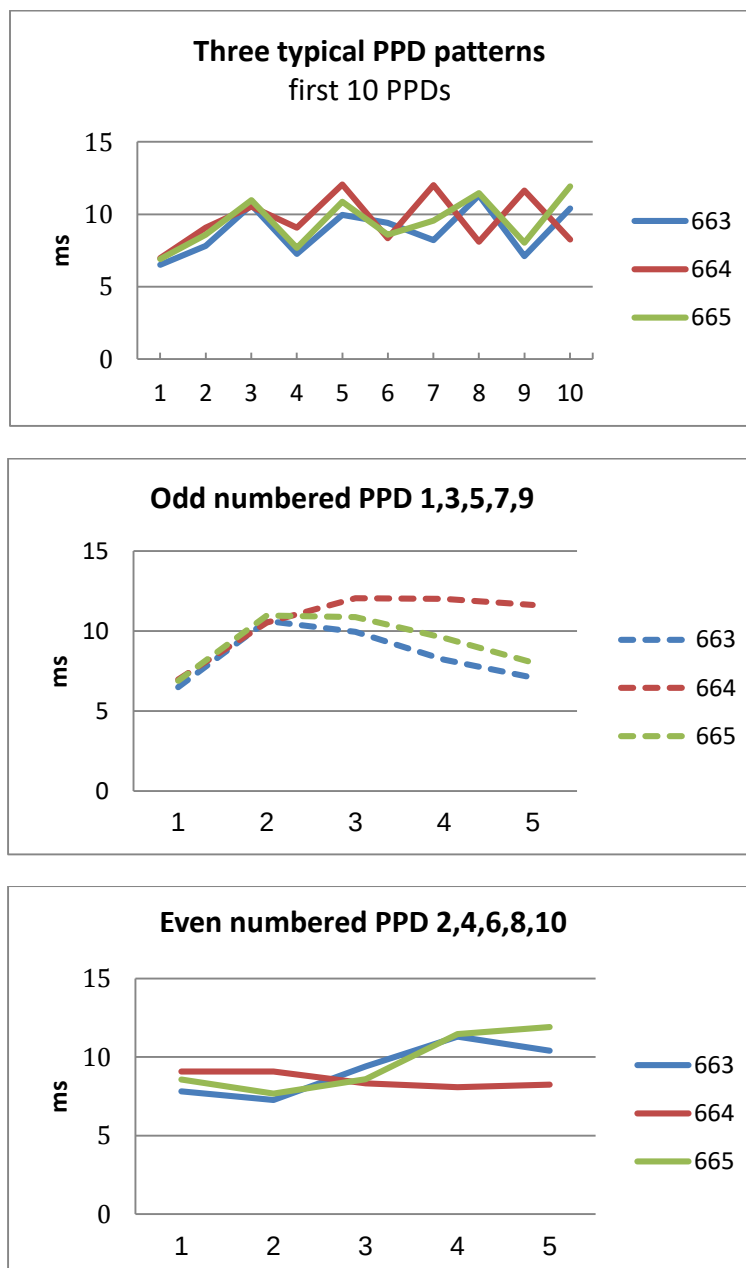
Figure 4. The same recording expanded. A 1 ms bar is added at the start of the pulse.



Observed acoustic structure from PPD analysis

Looking at the PPD patterns, there are often alternating high and low pulse duration values. If the odd numbered and even numbered PPDs are separately plotted, corresponding to the time taken to move between position A to B and position B to A (Figure 1), it appears that the time taken to cross one way is different to the time taken to cross back again and is roughly maintained. I see this as a mechanical resonance happening, a side to side movement of something that can occlude the syringe lumen and cause the double pulse or click, which forms the characteristic loud broadband sound. The first pulse to pulse duration (PPD 1) is short while the rattling oscillation initiates.

Figure 5. Three typical PPD patterns of 10 PPDs plotted together (A-B-A-B-A-B-A-B-A-B) and below the even and odd PPDs separated. (A-A-A-A-A) and (B-B-B-B-B).



Preliminary acoustic interpretation

The proposal is that the mechanism is like a rattling flap when the exhalation pressure and airflow gets high enough. The self-oscillating syllables are interspersed by inhalation minibreaths in the gaps which are 2 or 3 times longer than the syllables. The sound travels one kilometre or more. There is no loss of air volume so he can continue calling for hours. There is no large effort other than exhalation at higher pressure, rattling starts automatically, probably one side before the other if syrinx is asymmetrical. The double pulse is often noticeable on waveforms when each syrinx lumen is temporarily blocked at the start of the pulse.

Discussion

A mechanically constrained vocalisation

The Corncrake call is notable for its strongly mechanical acoustic character. The present hypothesis is that this character may result not from a simple absence of muscular control but from interaction with passive mechanical resonant properties of the syrinx, membranes, and airways. In this interpretation, a simple mechanical and individual resonance could contribute to a stable PPD pattern that persists within an individual for life.

Relationship to the Grey Swiftlet click mechanism

Suthers and Hector (1982) described a mechanism for echolocating clicks in the Grey Swiftlet that provides a useful comparative starting point for the Corncrake hypothesis. The important common feature is the generation of short, broadband, loud acoustic transients through events at the syrinx. The present manuscript uses this mechanism only as a conceptual comparison and does not claim that the Corncrake possesses the same anatomical mechanism.

Possible role of air sacs and the vocal tract

The interclavicular air sac surrounding the syrinx amplifies the vibrating tympaniform membranes and the trachea acts acoustically as a trumpet-like tube. The pharynx and open beak further influence radiation. Ruppell was the first to experimentally study the syrinx of several bird species and make the suggestion that tympaniform membranes act like a drum, amplified by the sounding box of the air sac that surrounds the syrinx and then further refined by the trumpet like trachea and open beak (Ruppell 1933).

Evolutionary and behavioural implications

The mechanisms producing short, precise clicks increases the propagation and temporal precision of the Corncrake call even though the species does not use the clicks for echolocation. However stable PPD patterns make males acoustically distinguishable by females, potentially allowing them to choose, without duplication, new partners for second broods.

Data Availability

Each year has all the recordings saved as separate WAV files in annual folders and the PPD measurements for each year are contained in annual XLSX files. All are accessible from the author.

Ethics Statement

The data for this study did not require capture, handling, invasive procedures, or experimental manipulation of live birds.

Funding

The author received no specific funding for this work.

Acknowledgements

My thanks to all the Skye crofters, residents, visitors and Shelagh Parlane (RSPB Skye Corncrake Project Officer) who shared reports of calling birds and recordings.

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