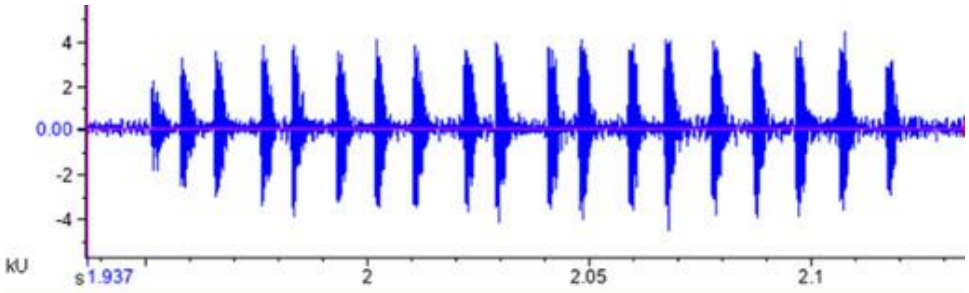
Syrinx structure and sound production in Corncrake calls.
R. Arnold. 21/1/2025

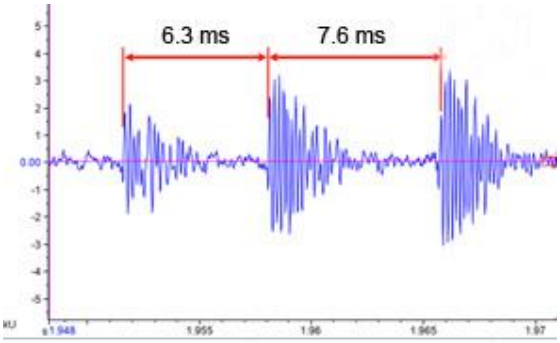
Notes made from observing sound recordings of Corncrake calls using Raven Lite software. It is an attempt to discover how the birds can make such a loud call for so many hours in the night.

Each syllable is made up of pulses, with gaps measured in milliseconds as ‘pulse to pulse durations’ or PPD.



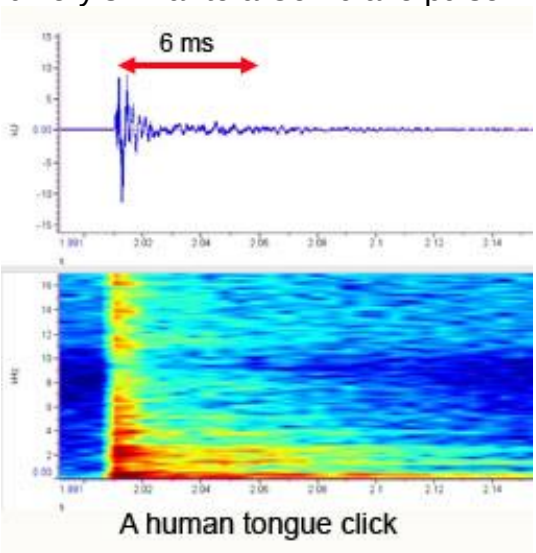
A syllable, 170 ms long with 19 pulses.

Each pulse enlarged, below, is in the same form as a tongue click that you can make by closing the airway in your mouth and opening it. The click happens on opening.



Corncrake pulses

A recording of a human tongue clicking. The airway opening causes a high frequency broad band sound very similar to a Corncrake pulse.

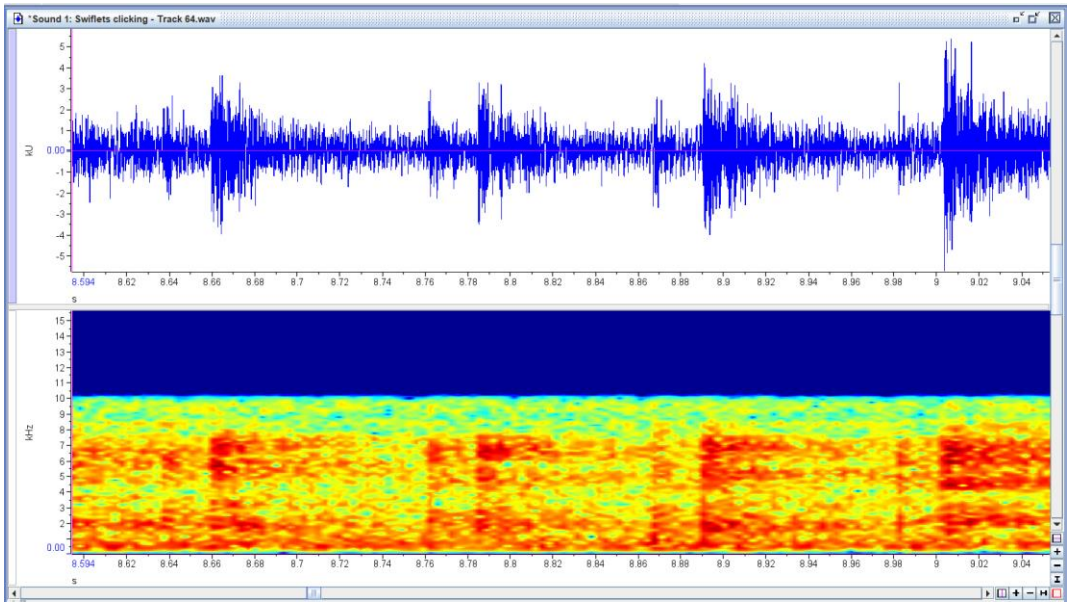


A human tongue click

The fast onset and broadband of frequencies (mostly up to 7kHz and higher) that are emitted by this clicking technique will improve penetration of the vegetation which might easily absorb a less harsh sound.

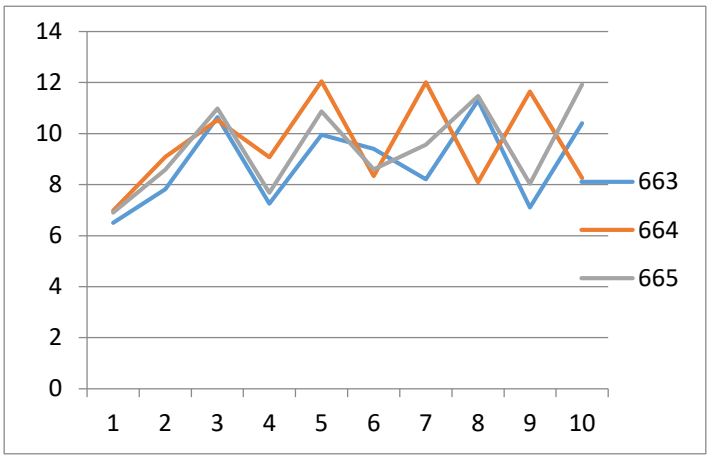
R. Suthers (2001) describes the mechanism of clicking for echolocation in Australian swiftlets and oilbirds. They use it to echolocate in caves. He shows how the short gap between phonations in bird song can be enough for an in breath or minibreath. The acoustic form of the click used for echolocation in swiftlets seems to be the same as a human tongue click and Corncrake click.

(Suthers. R.A. (2001) Peripheral vocal mechanisms in birds: Are songbirds special? Netherlands Journal of Zoology. 51 (2): 217-242)
(Ctrl + click to load)
http://robertarnold.co.uk/crex/suthers2001.pdf



Swiftlet clicking sound file from *Nature's Music*. 2004. Marler. P. & Slabberkoorn. H.

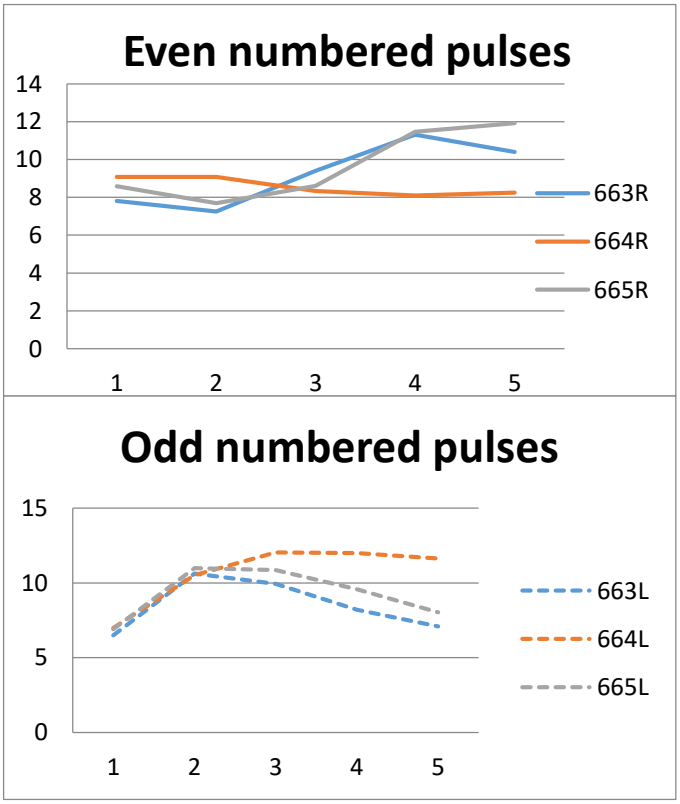
http://robertarnold.co.uk/crex/Swiflets_clicking_from_Track_64.wav



Three typically up and down PPD patterns

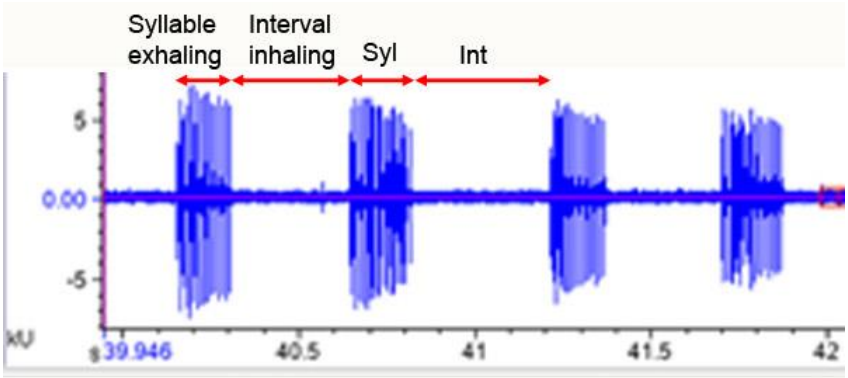
The three typical PPD patterns are displayed differently below. They show the length of time to the next click for even numbered pulses and for odd numbered separately. The simpler appearance of both charts suggests that the closure of one bronchus takes a different time to the other and combined together in the hypothetical oscillating system they display the typical up and down PPD pattern.

It suggests the clicks are alternating from one bronchus to the other by closing the airway and clicking on opening. Some anatomical flap like element moves from one side to the other, self-oscillating and requiring no muscular control. The call may be initiated by a small external muscle action on the syrinx to restrict the airway. There is also muscular compression of the air sacs by the sternum and hinged ribs. This produces the exhalation in the same way as the normal outbreath but with higher pressure.



The first pulse duration is always a short one, about 6 ms long in these recordings, as is shown in the odd numbered pulse chart.

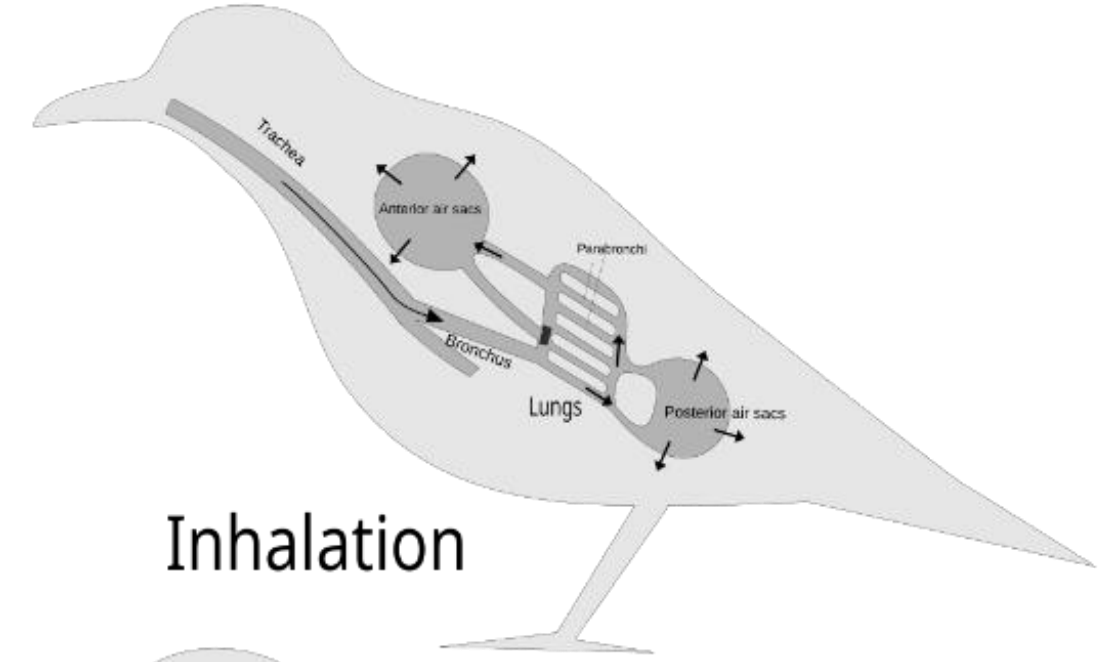
Syllables and intervals in a call



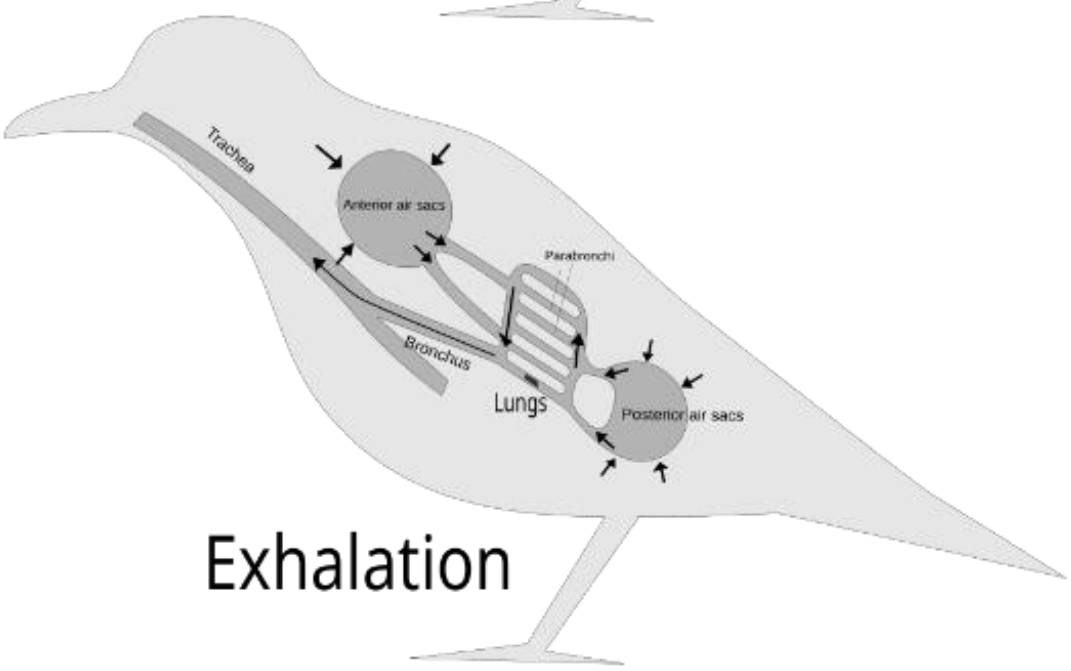
Two syllables in a call
Duration of call 1130 ms (1.13 s)
Duration of syllables 320 ms
Duration of intervals 820 ms

The bird's mood, for instance aggression to another male, can alter the spacing between the syllables, referred to as rhythm in the literature. However the PPD pattern of the syllable does not vary. It is very repeatable over days, months and even years. Suggesting a limited mechanical oscillating system with no conscious input by the bird.

The mass of air transported in and out during calling is balanced, there is no deficit to make up. Birds breathe using air sacs divided between the front and back of their body. The lungs are not compressed and allow air to pass through continuously in one direction. The air sacs inflating and deflating under muscular control, move the sternum and the hinged ribs, allowing short breaths to be made continuously and effectively. It is not tidal breathing as in mammals which have a diaphragm and compressible lungs that need to be filled and emptied. The Corncrake can make a short in breath between each syllable and maintain calling continuously and with little effort.
The mass of air is balanced between in and out breaths The air sacs do not get enlarged or depleted over time. So using Boyle's law the pressure times the volume equals a constant.



Inhalation



Exhalation

P - pressure, V - volume, R - rate of flow, t – duration, syl – syllable, int - interval

PV=c
V=R x t

$P_{syl} \times V_{syl} = P_{syl} \times R_{syl} \times t_{syl} = P_{int} \times R_{int} \times t_{int}$

A measure of effort could be the pressure times the rate of flow,
P x R.

Rearranging, $P_{int} \times R_{int} \times t_{int} = P_{syl} \times R_{syl} \times t_{syl}$

$P_{syl} \times R_{syl} / P_{int} \times R_{int} = t_{int} / t_{syl}$

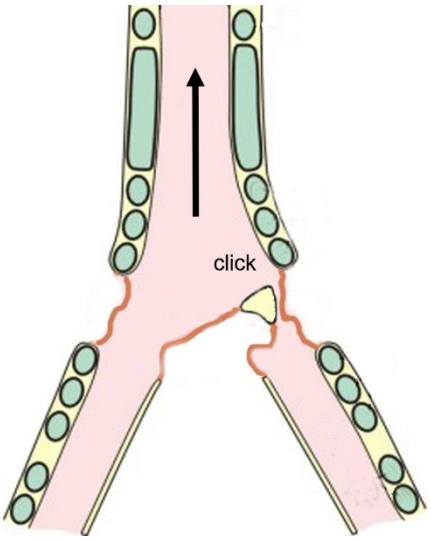
From the example in the chart above, and t_{int} = 820ms t_{syl} = 320 ms

$P_{syl} \times R_{syl} / P_{int} \times R_{int} = 820/320 = 2.6$

This means that the ratio of effort during calling between the sound producing exhalation period and the silent inhalation period is about 2.6 times. It is probable that the inhalation is at normal non-calling breathing flow rate and pressure, so the short time that is taken to make a syllable needs only a small muscular effort to increase the pressure and flow.

Syrinx structure in birds

A bird syrinx usually has two sound producing organs, one in each bronchus, at the base of the trachea. The PPD pattern evidence and sound analysis for Corncrakes suggest clicking by closure of alternate airways. A self-oscillating system creates a



series of mechanically determined spacings in time. Individual features and resonant frequencies of the physical structure of different birds generate slightly different PPD patterns. The trachea resonates to amplify the call.

Diagrammatic animation of some clicks at the opening of the bronchi during exhalation and the in breath during the intervals. (Ctrl + click to load)
http://www.robertarnold.co.uk/crex/crex-syllable.gif

Conclusion

Females can perform exactly the same syllables and intervals but without the rattling clicks. They must be lacking some part of the flapping syrinx valve that in the male occludes the airway temporarily and repeatedly, causing the clicks.

The calling mechanism has evolved to maximise transmission through dense vegetation to such an extent that it can be heard a kilometre away or more but the bird can be unseen. The energy used to do this has been minimised so that the bird can sustain it for hours with no rest and be findable at any time by a potential mate despite being invisible all night.