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LOW-FREQUENCY VOCALIZATIONS BY CASSOWARIES (*CASUARIUS* SPP.)

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Abstract.—Although some birds can detect wavelengths in the infrasound range, there has been little evidence that birds produce very low frequencies. We made nine recordings of a captive Dwarf Cassowary (*Casuarius bennetti*) and one recording of a wild Southern Cassowary (*C. casuarius*) near Crater Mountain, Papua New Guinea. Both species produced sounds near the floor of the human hearing range in their pulsed booming notes: down to 32 Hz for *C. casuarius* and 23 Hz in *C. bennetti*. Recordings of *C. bennetti* indicate four levels of harmonics with the 23 Hz fundamental frequency. Such low frequencies are probably ideal for communication among widely dispersed, solitary cassowaries in dense rainforest. The discovery of very low-frequency communication by cassowaries creates new possibilities for studying those extremely secretive birds and for learning more about the evolution of avian vocalizations. *Received 17 July 2002, accepted 14 June 2003*.

Resumen.—Aunque algunas aves pueden detectar longitudes de onda en el rango del infrasonido, existe poca evidencia de que las aves produzcan sonidos de muy baja frecuencia. Hicimos nueve grabaciones de un *Casuarius bennetti* cautivo y una grabación de un *C. casuarius* silvestre cerca de Crater Mountain, Papua Nueva Guinea. Ambas especies produjeron sonidos cerca del umbral auditivo inferior humano en sus notas pulsadas de pujido: de 32 Hz en *C. casuarius* y 23 Hz en *C. bennetti*. Las grabaciones de *C. bennetti* indican cuatro niveles de harmónicos con una frecuencia fundamental de 23 Hz. Estas frecuencias tan bajas probablemente son ideales para la comunicación en el bosque lluvioso denso entre individuos solitarios ampliamente dispersos. El descubrimiento de comunicación mediante frecuencias muy bajas en casuarios crea nuevas posibilidades para estudiar estas aves extremadamente sigilosas y para aprender más sobre la evolución de las vocalizaciones de las aves.

Bird vocalizations have fascinated humans for millennia and proved a rewarding research topic for decades in part because most birds sing within the audible range of humans (Wiley 2000). With the advent of sound-analysis equipment in the 1950s, it became apparent that many bird songs have levels of complexity indistinguishable to the human ear but which the avian ear can detect (Catchpole and Slater 1995). Despite the extensive research in avian vocalizations, there has been little evidence that birds produce frequencies inaudible to humans in the infrasound range. Usually frequencies under 20 Hz are considered infrasound, although there is considerable variation in what is considered the lower limit of the human auditory range (Payne et al. 1986). Although some birds can detect infrasound (Yodlowski et al. 1977), there has been relatively little study of birds' auditory abilities at low frequencies (Heffner 1998). Because very low frequencies propagate over vast distances with little attenuation, those frequencies are optimal for long-range communication (Garstang et al. 1995; Larom et al. 1997a, b), and it has been proposed that birds use environmentally produced infrasound during orientation and migration (Hagstrum 2001). Capercaillie (*Tetrao urogallus*) has an infrasound component in its song (Moss and Lockie 1979), but we are unaware of any other documented cases of avian-produced sounds that are below the human-audible range. Because most birds are small and lightweight, it is unlikely they are physically capable of producing such low frequencies. A large body size is required to produce low frequencies at any useful amplitude because the physical structures needed to produce them must be large in proportion to

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the long wavelengths of those tones (Penna and Veloso 1990). Few terrestrial vertebrates commonly produce and communicate at such low frequencies, elephants being a notable exception (Payne et al. 1986).

Cassowaries (*Casuariidae*) are the world's largest forest birds. *Casuarius casuarius* weighs up to 58 kg, whereas the smallest species, *C. bennetti,* weighs up to 29 kg. Those and a little-known third species, *C. unappendiculatus*, occur on the island of New Guinea, and *C. casuarius* also occurs in remnant rainforests of northeast Australia where it is endangered (Marchant and Higgins 1990). Despite their size, they are extremely secretive and remain poorly known (Westcott 1999). Ratites are considered a basal clade in birds, having a paleognathus palate and other presumed primitive characters (Stapel et al. 1984, but see Härlid and Arnason 1999) and probably diverged from other avian lineages in the Late Cretaceous (Cooper et al. 2001). As such, they have been considered good subjects for study of the evolution of auditory systems (Köppl and Manley 1997); study of their vocalizations could prove equally rewarding.

Cassowaries are known to produce a low booming noise (Coates 1985), but few recordings or analyses exist (Marchant and Higgins 1990). We collected and analyzed vocal recordings of two species of cassowaries to shed light on their vocal repertoire. Here, we show that cassowaries produce very low frequency sounds with components approaching the infrasound region.

METHODS

Field work was undertaken October–November 2001 in the Crater Mountain Wildlife Management Area of Papua New Guinea, where two species of cassowaries, *C. casuarius* and *C. bennetti*, occur. Four days were spent in lowland rainforests near Wabo, Gulf Province, taping for *C. casuarius*. A captive 2.5-year-old *C. bennetti* was recorded in Herowana Village, Eastern Highlands Province.

Recordings of *C. casuarius* were made with a Berhinger ECM-8000 measurement microphone (flat frequency response 20–20,000 Hz ±1 dB). To assist detection of low-frequency sounds at low intensities, the microphone signal was run through an amplifier (Rolls Mk3) and then to a custom-made filter box (Burns Electronics, New South Wales, Australia). That filter array contained an 800 Hz –25 dB low-pass filter, which was employed to remove as much of the ambient sound as possible while retaining and further amplifying the target frequency range. All recordings were made to a Sony D-100 Portable DAT Recorder (frequency response 20–20,000 Hz) and were written at a sampling rate of 48 kHz. A captive *C. bennetti* was recorded with the same recorder, but using a Sennheiser ME-66 microphone (40–20,000 Hz ± 2.5 dB).

Digital recordings were captured to hard disk at a sampling rate of 32 kHz and analyzed using SPECTRA PLUS 2.32 software (Sound Technology, Poulsbo, Washington).

RESULTS AND DISCUSSION

One vocalization of a wild *C. casuarius* was obtained. The calling bird was an unknown distance from the recordist, but was likely a significant distance away because of the low intensity of the received signal. The sole vocalization recorded consisted of six rhythmic pulses, each ~0.8 s long, for a total duration of 8 s. Frequencies produced by the cassowary extended down to 32 Hz (Fig. 1). Using an uncalibrated microphone and recording system, relative sound levels for the *C. casuarius* signal received were as high as 25 dB above the noise floor. If producing a series of harmonics, our equipment would not have detected components below 20 Hz. Possibly *C. casuarius* vocalizations extend that low. Future work will attempt to ascertain if there are such low components to the booming vocalization.

Nine vocalizations of the captive *C. bennetti* were obtained. Those were similar to the Southern Cassowary in being a series of pulsed booming notes, but with harmonics extending down to 23 Hz (Figs. 2 and 3). Characteristics of each booming sequence varied from a single long note of 3 s in duration to several shorter booms strung together over a 10-s timeframe. *C. bennetti* vocalizations recorded at the source consisted of two distinct components. A very loud roar-like pulse ranging from 200 to 100 Hz generally marked the beginning and ending of much lower and longer tones of similar intensity. Those low tones showed strong harmonics with the fundamental frequency ranging from 23 to 25 Hz. Four levels of harmonics were observed for most of the *C. bennetti* recordings and their frequencies were consistently 25, 50, 75, and 100 Hz. Relative sound levels 1.8 m from the source were recorded at up to 40 dB above the noise floor.

Natural selection should favor the evolution of vocalizations that reach their targets

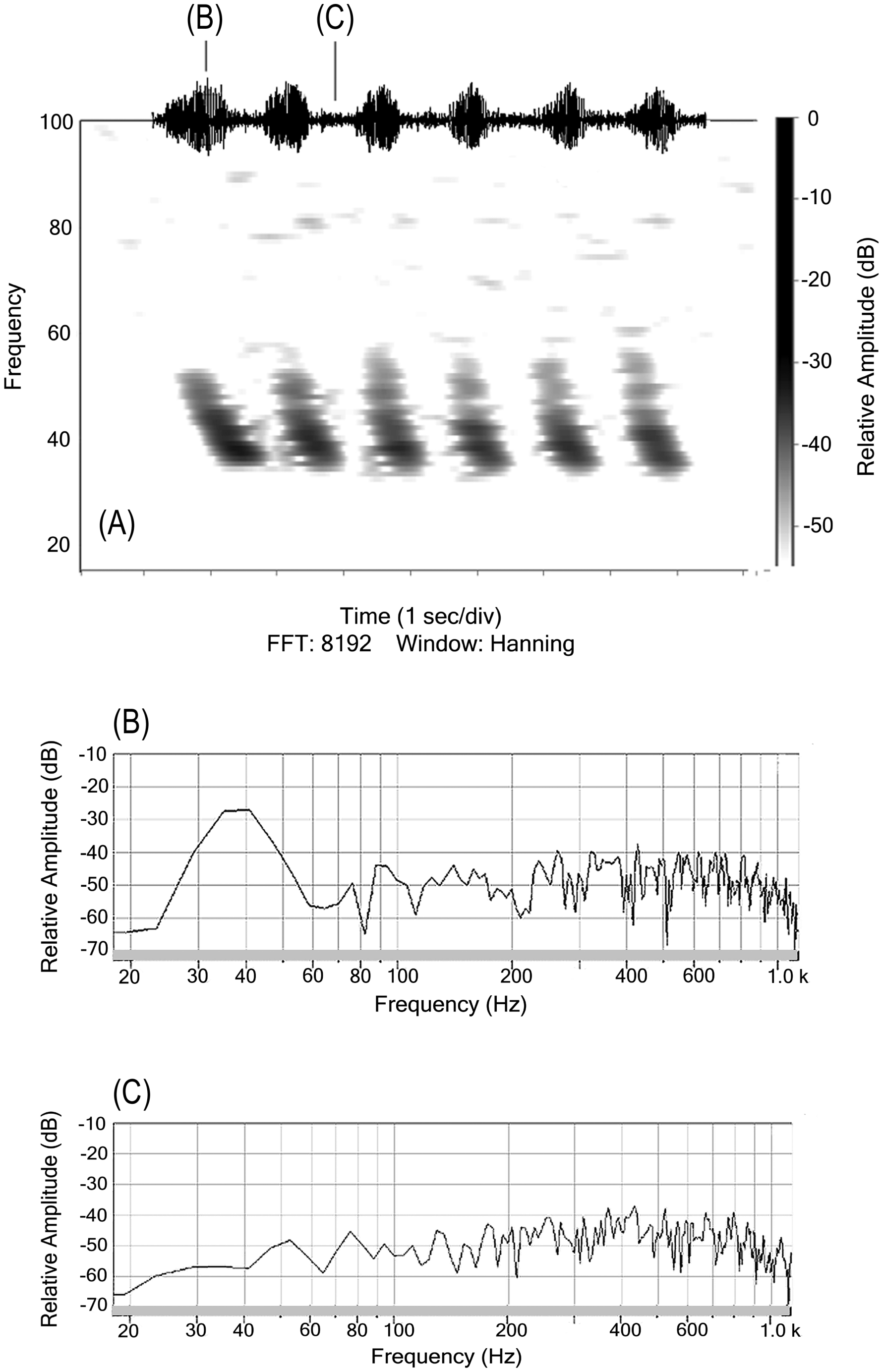
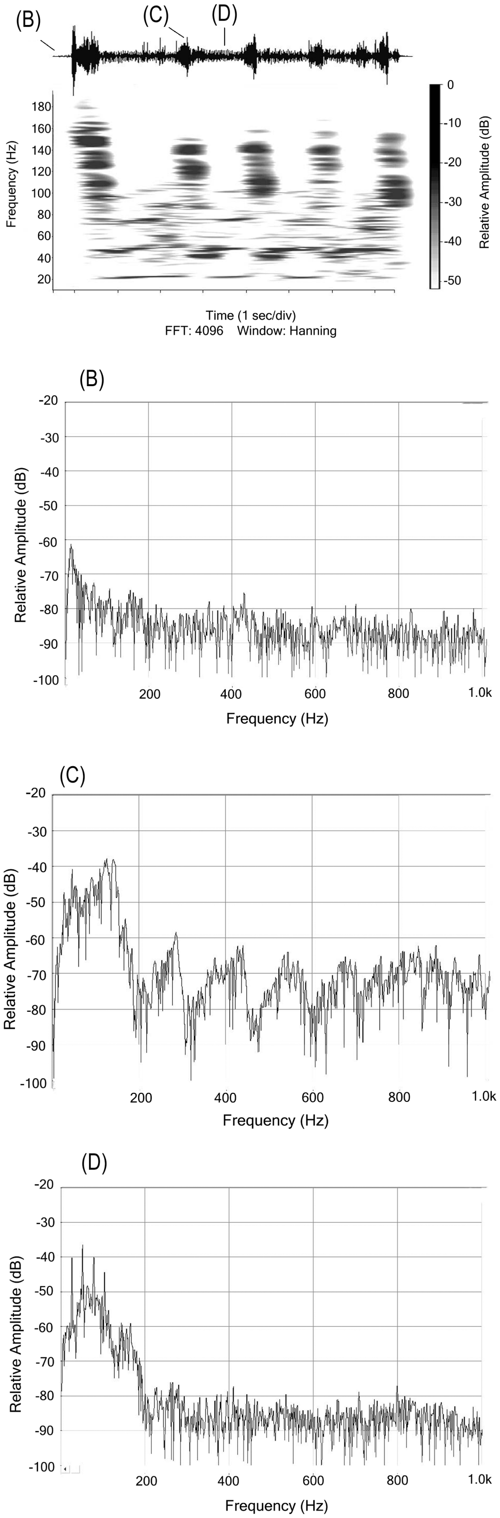


FIG. 1. (A) Audio spectrograph and wave form of a calling *C. casuarius* recorded near Wabo, Gulf Province, Papua New Guinea. The bird was an unknown distance from the recordist. The vocalization is barely audible to humans as a series of low booming notes. Panel (B) shows frequency and amplitude at the peak of the initial boom note. Panel (C) shows frequency and amplitude between booms, including background noise.



with minimal degradation (Endler 1992). Low frequencies propagate over long distances with minimal attenuation caused by vegetation (Marten and Marler 1977). New Guinea forests often have a fairly thick understory of wet leafy vegetation that could quickly attenuate higher frequencies. At Crater there are >370 stems >2.5 cm diameter at breast height per 0.1 ha (Wright et al. 1997). Wind, which attenuates low-frequency vocalizations (Larom et al. 1997b), is minimal beneath the canopy of tropical rainforests (Richards 1964). Possibly, the temperature boundary between the warm air above the canopy and cool air inside the forest could act as a sound duct (Larom et al. 1997a, b), increasing the range of a cassowary's low boom before it attenuates to background levels. Ground effect, causing the attenuation of low-frequency sounds (Wiley and Richards 1978), may be minimalized by the height of the bird or by the elevation of the selected broadcast site. In the dense rainforests of New Guinea, a low frequency would likely be an ideal means for sound-based communication between widely spaced animals such as cassowaries.

Auditory capability in cassowaries has never been studied. In their sister-group, Emus (*Dromaius novaehollandiae*), studies of chicks suggest infrasound could be heard by adults (Manley et al. 1997).

Both cassowary species produce sounds that extend to the lower edge of the human-audible range. When close to the bird, those calls can be heard and felt as an unsettling sensation (A. L. Mack pers. obs.), as reported also by observers of elephant infrasound vocalizations (Payne et al. 1986). Emus produce low-frequency vocalizations in the 60–80 Hz range, well above the lower range of cassowary booming (S. Halkin and C. Evans pers. comm.).

How cassowaries produce those low vocalizations is unknown and should reward future research. We observed the captive *C. bennetti* as

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Fig. 2. (A) Audio spectrograph and wave form of the booming sequence of *C. bennetti* recorded from a captive bird at Herowana Village, Crater Mountain, Eastern Highlands Province, Papua New Guinea. Panel (B) shows background noise prior to the boom, (C) shows frequency spectrum and peak amplitude of the roar-like pulse component of the calling sequence, and (D) shows the rumbling tones between pulses.

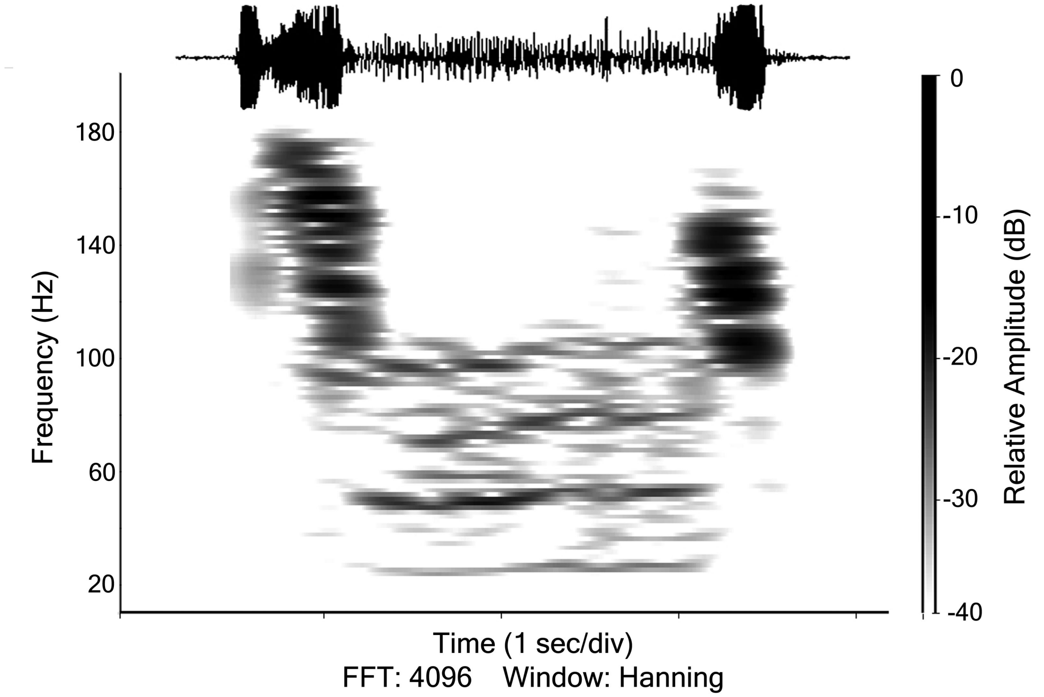

FIG. 3. Audio spectrograph and wave form of a single boom note recorded from a captive *C. bennetti* recorded from a captive bird at Herowana Village, Crater Mountain, Eastern Highlands Province, Papua New Guinea. Note the lower recorded intensity of the 25 Hz tone relative to the other harmonics present is likely due to the frequency response of the microphone, a Sennheiser ME66 (–5 to –10 dB at 25 Hz).

it produced the recorded boom notes. Prior to booming it made several gulping motions, possibly inflating internal air sacs. It then opened its bill wide, raised its body upward inhaling deeply, then threw its head down between its legs and began booming. At that position we could not see the head of the bird to ascertain if the bill was open or closed. The entire bird vibrated visibly during the booming. The colorful, wrinkled, naked skin at the back of the lower neck inflated tightly during vocalization, roughly doubling the apparent width of the neck. The heavily wrinkled skin of the neck allows for that significant expansion.

The analysis of the recorded *C. bennetti* calls showed strong harmonics at approximately 25, 50, 75, and 100 Hz with the fundamental frequency at 23–25 Hz (Figs. 2 and 3). Further study will be necessary to demonstrate how such signals are produced in cassowaries. Emus have a cleft in the trachea that is presumed to expand during vocalization (Murie 1867, S. Halkin pers. comm.). Whether cassowaries have such a cleft is yet to be determined.

All three cassowary species have keratinous casques rising from the upper mandible over the top of the skull up to 17 cm in height. The casque in living birds is spongy and resilient (Crome and Moore 1988) and the deeper regions of the casque are rich in a darkly pigmented sludge (Richardson 1991). Substantial speculation has arisen over the function of the casque. It has been variously proposed to act as a secondary sexual character, as a weapon in dominance disputes, as a tool for scraping the leaf-litter, or as a crash helmet for birds as they bash through the undergrowth (Crome and Moore 1988, Marchant and Higgins 1990). The later three seem highly unlikely on the basis of field observations. Fighting cassowaries butt their chests together and kick, keeping their heads back. Foraging cassowaries do not scrape the litter, they eat fresh fallen fruit. Running cassowaries keep the bill and eyes pointed forward, not downward as would need to be the case for the casque to act as a helmet (A. L. Mack pers. obs.). Future research should include the possibility that the casque might play some role in sound reception or acoustic communication.

Because cassowaries are so secretive and difficult to census (Westcott 1999) and because their low-frequency communications likely broadcast over large areas through even dense vegetation, there could be potential for using acoustic methods to assist in cassowary detection, tracking, and censuses (McGregor et al. 1997, Møhl et al. 2001, Wahlberg et al. 2001).

Cassowaries, the largest rainforest birds in the world, commonly produce very low-frequency vocalizations. Those calls could be a most effective means of communication between widely spaced animals in the dense and wet forests of New Guinea. That discovery opens many tantalizing avenues of study: How such low sounds are produced and received, and the possibility of acoustic monitoring to help study those secretive birds.

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