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The Cormorant Ear – Adapted to Underwater Hearing?

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ABSTRACT

Diving birds may spend several minutes underwater during foraging dives. However, surprisingly little is known about avian underwater hearing. We do not know their sensitivity or even if they respond to underwater sound. To help filling this gap we measured the audiograms of cormorants (*Phalacrocorax carbo sinensis*) and studied their ear anatomy. Wild-caught fledglings were anesthetized and their auditory brainstem response (ABR) to clicks and tone bursts was measured, first in an anechoic box in air and then in a large water-filled tank with their head and neck submerged 10 cm below the surface. The overall shape of their air-audiograms was like that reported for birds of the same size in air. The bandwidth and slopes of their audiograms were similar in air and water. However, in air the highest sensitivity was found at 2 kHz, whereas it was displaced towards lower frequencies underwater. These results suggest that cormorants have rather poor in-air hearing compared to similar-sized birds. Their underwater hearing sensitivity, however, is higher than what would have been expected for purely air-adapted ears. A possible reason for the poor in-air sensitivity is the special ear anatomy with the central eardrum shaped as a rigid piston like in turtles.

Keywords: Audiogram, Auditory threshold curves, Great cormorant

1. INTRODUCTION

In contrast to marine mammals little is known about the underwater hearing capabilities of diving birds. Since some diving birds may reach the same depths as marine mammals and experience the same potentially harmful anthropogenic underwater noise levels, it is important to obtain information about their underwater hearing.

Cormorants feed exclusively on fish and are known for their impressive foraging efficiency (1). During underwater pursuit of prey, they seem to rely mainly on vision, but their visual acuity is very low (2). So, they may use supplementary sensory information, for instance auditory information on prey movement and possible communication sounds. Therefore, they may be adapted to hearing underwater. They may have adaptations that protect their ears during diving and they may have adaptations that ensures high sensitivity to underwater sounds. The aim of the present study was to compare cormorant hearing in air with that underwater by measuring their hearing threshold curves in the two media.

2. MATERIAL AND METHODS

2.1 Experimental Subjects

Since it was not possible to use adult specimens, we collected fledglings from the nest in cormorant colonies and used 12 specimens for this study.

2.2 ABR Recordings

To measure their hearing threshold curves we used a setup similar to that of Christensen-Dalsgaard et al. (3) to record auditory evoked potential supposed to represent auditory brainstem responses

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(ABR). Subdermal electrodes behind the ipsilateral ear opening (active electrode) and on top of the head (inverting electrode) recorded the ABR-signals referred to ground by an electrode in the neck. Stimulus sounds (clicks and 25 ms duration tone bursts) and recorded ABR-signals were created and processed by Tucker-Davis equipment as (3). In air the deeply anesthetized birds were placed in an anechoic box with their ipsilateral ear 70 cm away from the speaker. In water their heads were submerged 10 cm below the water surface 45 cm from an underwater speaker, after subjecting the still deeply anesthetized birds to tracheostomy, such that they kept voluntarily breathing during measurements.

2.3 Ear Anatomy

Outer and inner ear anatomy was investigated by dissecting and photographing the ear under a surgical microscope.

3. RESULTS

3.1 Threshold Curves

Threshold curves (sound pressure levels) of the 12 subjects generally had similar shapes but varied greatly in sensitivity (ranges 15-30 dB in air and 10-40 dB underwater). Figure 1 shows a representative example of threshold curves in air and underwater for a single specimen. In general, the low-frequency slopes of the threshold curves were very similar, whereas the high-frequency slopes in air were steeper than those underwater and the best frequency in air was at a higher frequency (2 kHz) than underwater (1 kHz). However, the lowest threshold was much the same when comparing ABR-responses in air and underwater.

Threshold curves may also be expressed in energy terms (sound intensity levels) by relating the dB-values to 1 pW/m^2 by further subtracting 36 dB from the underwater threshold curves in Figure 1 (for further explanation of this conversion see e.g. 4).

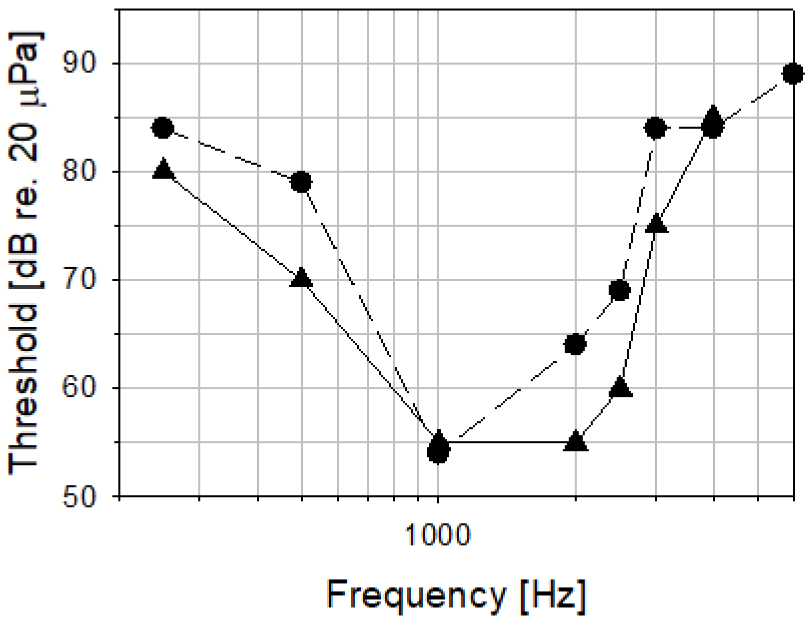

Figure 1 – Threshold curves in air (triangles) and in water (circles) for a single fledgling (individual H). In air the dB reference value is 20 µPa, whereas in water it is 1 µPa. To compare threshold curves in air and water both have been referred to 20 µPa by subtracting 26 dB from the underwater threshold values (for further explanation of conversion see e.g. 4)

3.2 Anatomy

The ear opening was comparatively small and easily compressible, and the ear canal was bent such that the eardrum was invisible from outside. The eardrum was difficult to delineate as it appeared very flat and thick with the extra-columella covering a substantial fraction of its inner surface.

4. DISCUSSION

4.1 Adaptations to Underwater Hearing

The cormorant threshold curves in air were shaped like those of other diving birds (5) but less sensitive (6). In comparison, their underwater hearing thresholds were as good (expressed as sound pressure levels) or better (expressed as sound intensity levels) than those in air. So, although we do not know whether cormorants use their underwater hearing to obtain supplementary sensory information during pursuit-dive foraging, they definitely have the potential of doing so.

The anatomy of the outer ear and ear canal could be interpreted to serve as protection of the ear during diving. Their surprisingly high sensitivity under water could be caused by an anatomical adaptation making the eardrum flat and thick, almost like that observed in turtles (3). A recent study (7) suggests that such a plate-like tympanum is more efficient than a protruding thin membrane in coupling sound energy in water to the inner ear.

5. CONCLUSIONS

The results suggest that cormorants have rather poor in-air hearing compared to similar-sized birds. Their underwater hearing sensitivity, however, is higher than what would have been expected for purely air-adapted ears. A possible reason for the poor in-air sensitivity is the special ear anatomy with the central eardrum flat and thick, and shaped as a rigid piston like in turtles.

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