

## Some characteristics of hearing of the Brazilian manatee, *Trichechus inunguis*

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### Introduction

The auditory system of Cetaceans and Pinnipeds was the subject of extensive study by many authors (Fobes & Smock, 1981; Popper, 1980; Watkins & Wartzok, 1985). On the other hand, the auditory system of another order of aquatic mammals, the Sirenians, remains virtually unstudied. The Sirenians present a quite different type of adaptation to aquatic environment as compared with the Cetaceans and Pinnipeds, and the systematic positions of the three orders are rather different. So, the comparative study of the auditory systems of the Sirenians and other aquatic mammals is of interest.

The present paper is concerned with quite a rare species of Sirenian, the Brazilian manatee, *Trichechus inunguis*. The study was carried out at the 'Quisto cocha' biological station, Institute of Investigation of Peruvian Amazony (IIAP), Iquitos, Peru.

Like all Sirenians, the manatee is a slowly swimming plant-eating animal. There are no data on echolocation in manatees or other Sirenians. However, it is known that manatees produce underwater vocalization within the sound frequency range of up to 10 kHz (Schevill & Watkins, 1965; Evans & Herald, 1970; Sonoda & Takemura, 1973). Manatees have normally developed brain stem acoustic centres (Verhaart, 1972). These data suggest that manatee hear rather well. However, up to now a single physiologic study has been conducted on hearing in a manatee's (Bullock *et al.*, 1980). In that study auditory evoked potentials were recorded from the surface of the manatee head. The animal was in air during those experiments. The evoked responses to clicks and tone bursts were obtained when a speaker was in air. The evoked responses recorded were supposed to be generated by the auditory cerebral cortex.

In the present study we also recorded the auditory evoked potentials. However, not cortical but short-latency auditory brain-stem responses (ABR) were the main subject of our study. The recording of ABR is easy and harmless for an animal. Moreover, the ABR method gave rather extensive data on some other species of aquatic mammals, namely, the dolphins (Ridgway *et al.*, 1981; Popov & Supin, 1985,

1987; Supin & Popov, 1985). This makes it possible to compare the characteristics of audition of the dolphins and the manatee as measured by the same method.

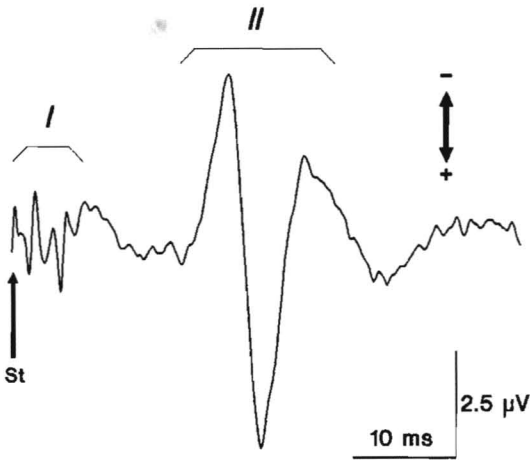
### Material and Methods

One young female *Trichechus inunguis* with body weight 50 kg was under study. Between the experiments the animal was kept in a pond. During the experiment it was placed in a plastic bath (1.4 × 2.2 × 0.4 m) filled with fresh water. The animal was supported by a stretcher so that the dorsal surface of the head and the back were above the water surface. Since no surgical procedures were used, the animal was neither anaesthetized nor curarized. Each experiment lasted for 2–3 hours, after which the animal was placed back into the pond where it was kept.

Electrodes for recording the ABR were thin needles inserted 2–3 mm into the skin. No signs indicating painfulness of such a procedure for the animal were observed. Potentials were recorded monopolarly. An active electrode was placed in the dorsal part of the head, a reference electrode in the back, both electrodes above the water surface. Potentials were amplified in the frequency range 100–5000 Hz and 1000–2000 samples were averaged to obtain a single ABR.

Different kinds of signals (clicks, noise and pure tone bursts) were used as acoustic stimuli. They were delivered through a spherical piezoelectric ceramic transducer, 6 cm in diameter, immersed in water. To produce noise bursts, the transducer was activated by a pseudo-random binary signal with the pace duration 8 μs; to produce a click the transducers were activated by 10 μs long rectangle pulses. Noise bursts and clicks had a spectrum range of 5–110 kHz with spectrum irregularity of up to 10 dB within the range of 20–90 kHz.

Frequency of tone signals varied within a range of 5–70 kHz. Noise bursts and tone signals were formed by an electronic switch. Noise bursts had abrupt



**Figure 1.** Evoked potentials recorded from the manatee's head surface in response to sound click (100 dB). I, the fast evoked response (ABR); II, the slow (cortical) evoked response. St, the stimulation moment.

rise/fall, while tone signals were characterized by a linear rise and fall with rise/fall time 0.1 or 0.2 ms.\*

Sound intensities from 0.1 mPa† to 100 Pa were used for stimulation, i.e. from -20 to 100 dB relative to 1 mPa. Actual sound signal characteristics (intensity, shape, duration and frequency spectrum) were monitored by a hydrophone with a pass band of up to 150 kHz. The hydrophone was located near the animal's head, 1-3 cm from the auditory meatus.

**Results**

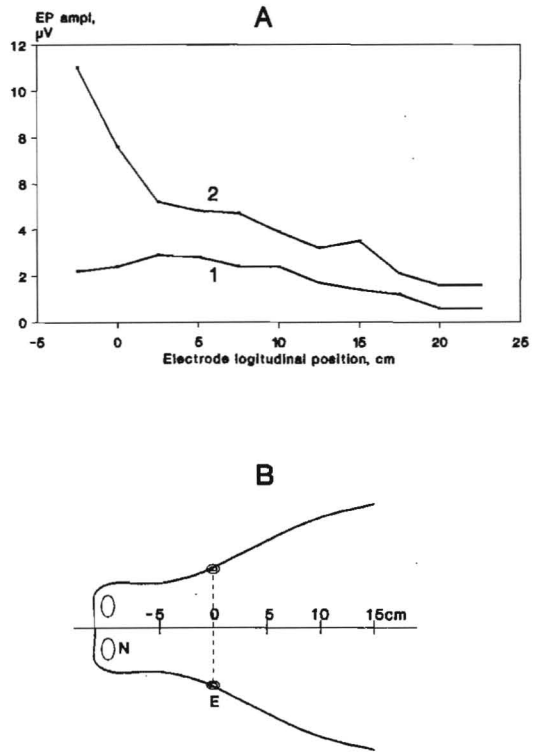
*Shape and location of auditory evoked potentials in the manatee*

Evoked responses, to clicks of 100 dB, recorded from the manatee's head surface are demonstrated in Fig. 1. They consisted of two main parts: the initial fast wave complex I and the second slow wave complex II. The first one consisted of a sequence of short waves, each lasting about 1 ms—it was the ABR. The second one consisted of slower waves lasting 5–10 ms. It resembles in some respects the cortical responses described by Bullock *et al.* (1980), however in our case these waves were less prolonged.

Fig. 2 demonstrates the dependence of amplitude of the ABR and the slow (cortical) response on the position of recording sites at the animal's head; the amplitudes of the both responses were measured from peak to peak. The slow response had the maximal amplitude in the most frontal recording sites.

The ABR amplitude was maximal in the vicinity of the mid-dorsal line, 2.5–5 cm caudal to the line

\*ms = millisecond.  
†mPa = milliPascal.



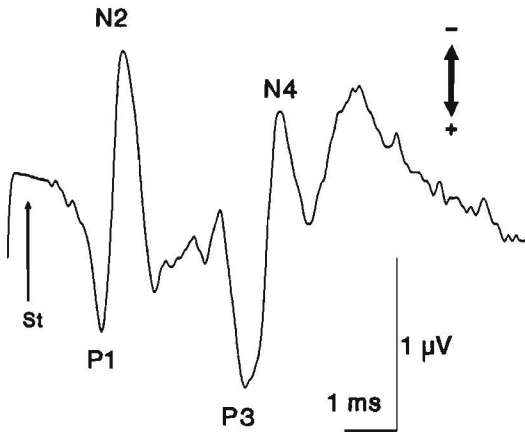
**Figure 2.** A, dependence of peak-to-peak amplitude of the ABR (1) and slow evoked response (2) on position of the recording electrode. Electrode position is indicated as a distance from the line connecting the eyes, according to the scale in B. B, scheme of the dorsal view of the manatee's head; N, nostrils; E, eyes.

connecting the eyes. Moving off from this region, the response amplitude decreased at relatively low rate so that responses of considerable magnitude were recorded even at a distance of 15–20 cm from the focus. Taking into account these observations, the active electrode in all further experiments was located about 5 cm caudal to the eyes level, while the reference electrode was placed on the back.

Of these two response types, the ABR was considered in more detail.

*ABR shape and characteristics*

ABR recorded from the manatee's head surface is presented in Fig. 3. It consisted of sequences of waves, each lasting about 1 ms. The response latency with the acoustic delay taken into account (i.e. from the moment an acoustic impulse reached the animal's head) constituted 0.9–1.0 ms for clicks of high intensity. The main waves of ABR are designated in Fig. 3 as P1, N2, P3 and N4 (P-positive, N-negative). Wave peak latencies for clicks of high intensity had the following values: P1, 1.4 ms; N2, 2.1 ms; P3, 4.5 ms



**Figure 3.** ABR recorded from the manatee's head surface. St, the moment when an acoustic pulse reaches the animal's head. P1–N4, designation of ABR waves.

and N4, 5.2 ms. Some additional little waves that could be observed are not designated here. The maximum ABR amplitude between the peaks N2 and P3 constituted 2–3  $\mu\text{V}$  for stimuli of high intensity.

#### *Dependence of ABR on intensity of clicks and noise bursts*

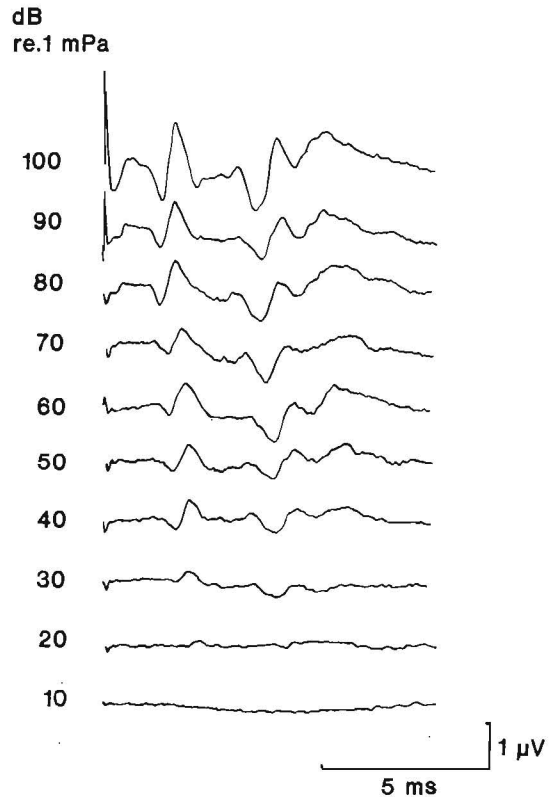
Fig. 4 demonstrates ABRs evoked by clicks of varying intensity. There is an increase in the response amplitude with an increase in the stimulus intensity. The shape remained almost unchanged. Slight shortening of latencies of the main waves was observed with increasing the intensity.

The dependence of the maximum response amplitude measured between the peaks P1–N2 on the click intensity is shown in Fig. 5(1). The amplitude reached its maximum at 100 dB. At sound intensities of up to 100 dB the dependence of the response amplitude on the stimulus intensity was linear and could be approximated to a regression line. The ABR threshold was evaluated by extrapolating the regression line to its intercept with the abscissa. For clicks the threshold determined in such a way was about 20 dB re. 1 mPa.\*

The dependence of the response latency (peak latency of the P1 wave) is shown in Fig. 5(2). The latency fell with increasing the intensity. This dependence was virtually linear in the intensity range from 20 to 90 dB. A regression line approximating this part of the plot had the slope of about 8  $\mu\text{s}/\text{dB}$ .

Onset of a noise burst caused ABR of the same shape as that evoked by clicks, and the dependence of this response on the stimulus intensity was similar (Fig. 6). The threshold evaluated from the plot

\*Relative to a level of 1 mPa.



**Figure 4.** ABRs evoked by clicks of different intensity. Click intensity is indicated near the curves in dB re. 1 mPa.

intercept with the abscissa was about 20 dB re. 1 mPa.

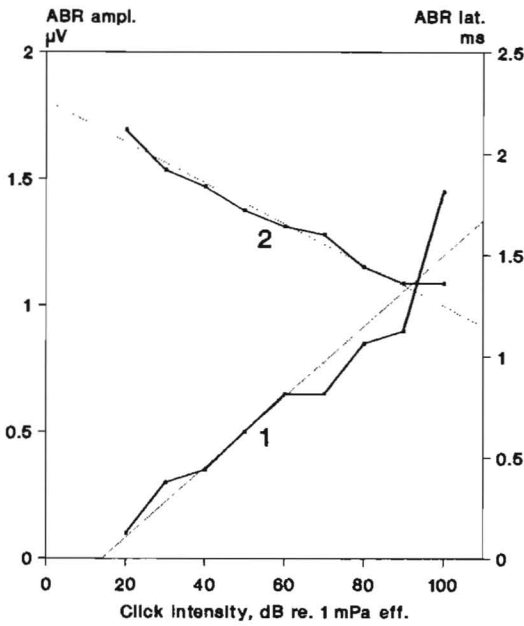
#### *Dependence of ABR on tone intensity and frequency; audiogram*

Onset of a tone burst caused ABR of the same shape as that evoked by clicks or noise bursts. The ABR amplitude in this case depended both on the tone intensity and frequency, and their thresholds depended on the tone frequency.

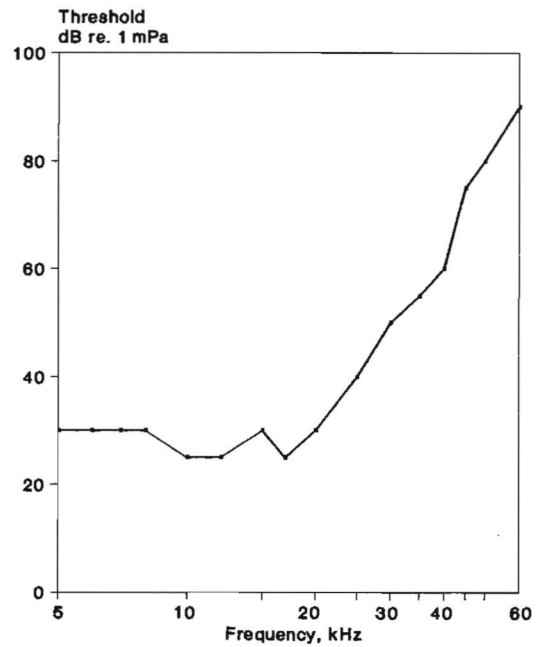
The audiogram reflecting the dependence of the ABR thresholds on the frequency of a tone burst is presented in Fig. 7. The lowest thresholds at frequencies from 5 to 20 kHz were about 25–30 dB. A rise of the ABR thresholds took place at higher frequencies. The maximum frequency at which ABR appears ran to 60 kHz. At this frequency the response threshold was above 90 dB re. 1 mPa, i.e. 60–65 dB higher than the minimal thresholds at lower frequencies.

#### *Dependence of ABR on Rhythmic Stimulus Rate*

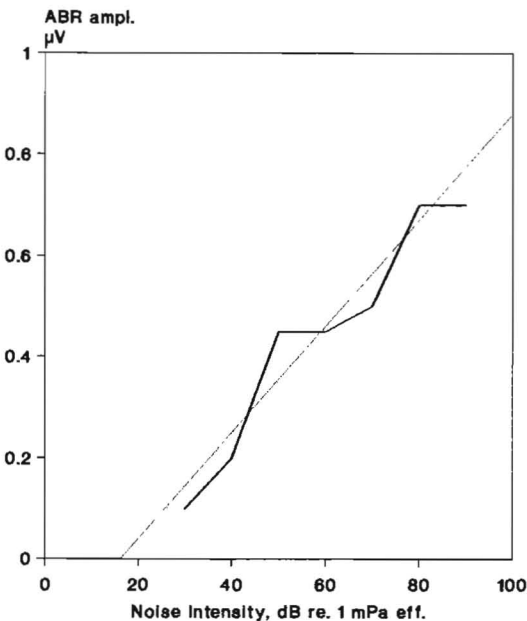
The ability of responses to follow rhythmic stimulation appears to be an important parameter of the



**Figure 5.** Dependence of ABR amplitude (1, left scale) and latency (2, right scale) on click intensity. The amplitude was measured between peaks P1–N2 (see Fig. 3), the latency was that of P1 peak. Dotted straight lines, regression lines approximating the plots slope.



**Figure 7.** Dependence of ABR threshold on tone frequency (the audiogram).



**Figure 6.** Dependence of ABR amplitude on noise burst intensity. The amplitude was measured between peaks P1–N2 (see Fig. 3). Dotted straight line, regression line approximating the plot slope.

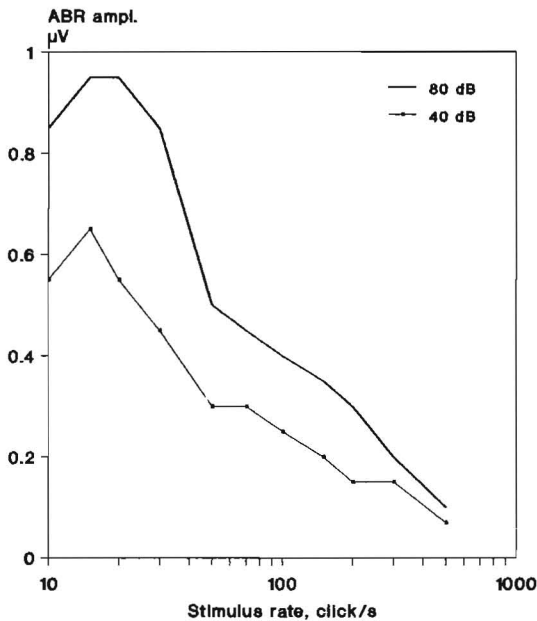
auditory system. For measuring this characteristic in the manatee we recorded ABR evoked by rhythmically repeated clicks of various rates.

The response shape and amplitude were slightly changed at stimulus rates up to 20/sec. Further increasing of the rate resulted in a gradual decrease of the amplitude and in smoothing of the response.

Fig. 8 presents plots of the amplitude of auditory responses versus the rate of rhythmic stimulation. At a lower stimulus rate the ABR amplitude was measured between peaks P1–N2; at higher rates when the response was smoothed, the amplitude of these smoothed waves was measured. As shown in Fig. 8, the shape of the plots was similar at different stimulus intensities from 40 to 80 dB, excepting different response amplitudes. The ABR amplitude was diminished when the stimulus rate was increased above 20/sec and the ABRs were able to follow rhythmic stimulation at rates up to 500/sec.

## Discussion

The existence of several waves in the manatee's ABR indicates that different parts of the auditory system participate in generation of this response. Only the main four waves of the ABR were designated in this study, however, its real composition appear to be more complicated.



**Figure 8.** Dependence of the ABR amplitude on rhythmic click rate at two stimulus intensities (80 and 40 dB re. 1 mPa).

ABR duration in the manatee is somewhat longer than that in dolphins (Ridgway *et al.*, 1981; Popov & Supin, 1985, 1987) and its shape is quite different. Another significant difference between the ABRs in the manatee and the dolphins is a significantly lower amplitude of the response in the manatee—about 10-fold lower than in dolphins. It may be due to less developed brain-stem auditory centres in the manatee as compared with dolphins. However, magnitude of the auditory evoked responses may depend not only on the development of the brain auditory centres, but also on their anatomical peculiarities and spatial position.

The auditory thresholds in the manatee revealed by the ABR recording were significantly (about 25–30 dB) higher than those in Cetaceans and Pinnipeds (see Fobes & Smock, 1981; Watkins & Wartzok, 1985). The frequency range of hearing in the manatee (up to 60 kHz) was narrower than that in Cetaceans (120–150 kHz in dolphins) and was close to that of Pinnipeds.

Audiograms obtained in dolphins by ABR recording (Popov & Supin, 1985, 1987) were in good agreement with the data of behavioural studies (see Popper, 1980; Fobes & Smock, 1981). It could be suggested therefore that the audiogram obtained in the manatee by the same method does also reflect real characteristics of its hearing.

The ability of ABRs to follow rhythmic stimulation in the manatee (up to 500/sec) is not so high as in dolphins (more than 1000/sec) (Ridgway *et al.*, 1981; Supin & Popov, 1985; Popov & Supin, 1987). It is possible that the ability of dolphin's ABRs to recover their responsiveness exclusively quickly is associated with echolocation, and this ability is absent in the manatee.

All the results presented above indicate that the manatee does not have such exclusively high auditory abilities as those of Cetaceans. These differences may depend on differences in their ecology and mode of life.

Of course, our data, which were obtained in the single animal, are preliminary and the problem needs further study. However the data presented herein characterize to some extent the auditory abilities of this interesting aquatic mammal.

### Summary

Auditory brain-stem responses (ABR) and slower auditory cortical responses were recorded from the head surface of a non-anaesthetized and non-relaxed Brazilian manatee, *Trichechus inunguis*. The ABR was used to measure some characteristics of the manatee's hearing. The region of best ABR recording was shown to be located 2–5 cm caudal to the line connecting the eyes. The threshold values were about 25 dB re. 1 mPa for clicks and for tone bursts of the optimal frequency (5–20 kHz). The maximum sound frequency at which ABR could be evoked was 50 kHz. ABRs were able to follow rhythmic stimulation at rates up to 500/sec.

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