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PROPERTIES OF THE AUDITORY SYSTEM IN BIRDS AND THE EFFECTIVENESS OF ACOUSTIC SCARING SIGNALS

Karl J. Beuter and Rainer Weiss,
Battelle Frankfurt

1 SUMMARY

The effectiveness of sound signals for scaring gulls away from feeding areas have been investigated during the last years. Physiological and behavioural data were used to identify the most promising approach. Ultrasound and infra-sound were tested as well as audible sound at different frequencies and with a large variety of modulations.

The investigations have shown that ultrasound and infrasound do not produce the desired scaring effect, where as a group of frequency-modulated audible signals have proved effective for bird control. The scaring signal can be generated by an electroacoustic device. Based on the encouraging results of investigations conducted on behalf of two major German cities, functional models of the bird control device have been developpped for an industrial client.

Fundamental properties of the bird's ear and some results of a field test to scare away gulls from waste deposits are described in the following paper.

2 IMPORTANCE OF ACOUSTIC SIGNALS

Birds can be scared away by humans, animals, scarecrows, light, microwaves, aircrafts, chemicals and sound. But laws and environmental protection make it necessary to select carefully among the different methods /1/. Automatic or controlled operation is also often desired. Important selection criteria for scaring devices ar their

- Efficiency
- Ease of operation and
- Compatibility with the environment.

These criteria may contradict each other in some cases. For instance, a very effective chemical can pollute the water, or another technique may need a full time operator. As a consequence, it is generally not possible to find a device which fulfills all selection criteria. So one should try to find specific solutions for given applications.

Acoustic methods offer some interesting advantages /2/:

- Acoustic signals have important functions in the behaviour of birds.

- Sound is a relatively far reaching signal and is well suited to cover large areas.

- Acoustic signals can be easily combined with other effects to produce conditioning stimuli.

All kinds of sound-wave emitting equipment will be considered here as potential bird scaring device, no matter if the sound is in the normal hearing frequency range of humans or at ultrasonic or infrasonic frequencies. Mechanical sound sources, pyroacoustics, guns, electroacoustic generators and ultrasound sirens are typical acoustic bird scaring devices.

This article deals mainly with gulls, a bird species which is important in bird strikes due to its relatively high bodyweight and its appearance in large flocks. The method used in gulls can be applied to find appropiate sound signals for other species like crows, starlings, peewits, pigeons and possibly birds of prey.

3 EFFECTS OF SOUND IN HUMANS AND ANIMALS.

3.1 Physical characteristics of sound.

The subjective loudness is closely related to the sound pressure level, measured in dB re 0,00002 Pa. In short pulses, the duration of the signal contributes to the perceived loudness, too. The pitch of a pure tone is physically-described by its frequency in Hz and the structure of a complex sound is in part described by its frequency spectrum.

The sensitivity of the hearing organ is not constant over the hearing frequency range but depends strongly on frequency. In order to estimate the subjective effect of sound signals, one has to consider the spectral sensitivity of the ear. A good indicator for the spectral sensitivity is the auditory threshold, which has been measured for many species.

Auditory threshold curves for birds are given in fig.1 and for humans in fig.2. One can see, that in the neighborhood of regions of best hearing there exist frequency ranges with clearly reduced sensitivity. These regions are obviously species specific and differ strongly between mammals and birds.

Therefore, the resulting perceived loudness depends on the incoming sound pressure level weighted by the frequency-dependant auditory sensitivity function. Since the sensitivity function is different in humans and in birds, the resulting subjective loudness will be different as well.

The sound pressure level and the frequency spectrum are only the most simple physical parameters to characterize sound signals. But there are many more significant features, which contribute to the information contained in the signal. The essential components in the acoustical communication signals of birds are generally not yet known and must be identified very thoroughly in behavioural experiments under natural conditions.

3.2 Communication signals

Communication signals often exhibit complex frequency-time-structures and they are species specific. Human language covers the frequency range between 250 Hz and 10 kHz, but communication is still possible in a limited frequency interval between 500 Hz and 2500 Hz. The peak sound pressure levels at 1 m distance and normal speech are about 60 dB and about 75 dB during shouting. Singing birds use sound pressure levels at about 70 dB, but much higher levels e.g. 120 dB in echolocating bats have been observed in bioacoustics. The highest frequencies with about 130 kHz have been measured in bats and in dolphins. Rodents, for example mice, use ultrasound up to 90 kHz /3/. In bird songs only frequencies up to 10 kHz have been found. At the lower frequency end of bird songs, several hundred Hz were observed.

3.3 Biological effects of sound

The ear is the adequate and most sensitive organ for sound reception. Depending on the structure and behavioural meaning of the sound stimuli one can achieve dramatic effects at very low sound intensities.

High sound pressure levels result in temporary loss of hearing sensitivity (temporary threshold shift). Permanent or frequent exposition to these levels may cause permanent damage. This occurs typically at levels above 80 dB. At much higher levels of about 130 dB sound causes pain in humans. At this level extraaural effects like sickness start to occur. Ultrasound and Infrasound at levels above 140 dB have similar effects.

Technically it is very difficult or expensive to produce and radiate sound signals except bangs at levels above 130 dB. Therefore, acoustical devices should use the high sensitivity of birds in response to behaviourally relevant sound structures and should not try to produce uncontrolled effects on birds by high acoustic energies.

3.4 Hearing thresholds in birds and small mammals

In general, the upper edge of the hearing frequency range increases, as the body weight decreases. This has been verified in mammals, but not in birds. The upper frequency edge in the hearing threshold of mice and the corresponding frequency contents in their communication sounds is at about 80 kHz, but one cannot find similarities in the auditory data of birds. As ~hown in fig.2, the frequencies of best hearing in birds are between 1 kHz and 4 kHz and very high threshold levels in birds start below 11 kHz.

From these data one can conclude that birds are unable to hear frequencies above 11 kHz. Therefore hearing sensitivity at ultrasonic frequency in birds can be excluded. In addition, there are no hints from behavioural experiments or from sound recordings which give any evidence that ultrasound could be meaningful for birds.

4 METHODS FOR MEASURING THE SCARING EFFICIENCY OF SOUND SIGNALS

Audible sound, infrasound and ultrasound were used as stimuli for gulls in neurophysiologigal and behavioural experiments. In the neurophysiologigal study, evoked potentials from the midbrain of gulls were measured. With this very sensitive method hearing thresholds from 1 Hz up to 25 kHz were determined.

Experiments with free living gulls were conducted in a municipal purification plant. The high number of animals and the easy access to the plant allowed us, to place the sound sources very near to the animals and to apply high sound intensities. The sound sources were positioned several days before the experiment took place. So the gulls were used to the equipment. The scaring efficiency of the sound signals was registrated on a scale from one to six.

5 RESULTS

5.1 Neurophysiology

<u>Ultrasonic hearing threshold:</u>

In four animals measurements were taken between 16 kHz and 20 kHz and in one animal up to 25 kHz. Stimuli up to 110 dB at the ear were used. No indication for hearing was found.

<u>Infrasonic hearing threshold:</u>

In guinea fowls a remarkable low infrasound hearing threshold similar to that in pigeons had been measured. With the same method no indication for hearing in the gulls was found.

<u>Hearing threshold between 20 Hz and 16 kHz:</u>

The hearing threshold, determined by electrophysiology, is given in fig. 3. The frequency of best hearing is at about 3 kHz. It is remarkable, that the auditory sensitivity of gulls declines rapidly at lower frequencies. At frequencies below 500 Hz the hearing threshold is above 40 dB.

5.2 Ineffective sound signals

Infrasound of 8 Hz and 10 Hz at levels up to 85 dB could not generate any reaction of the gulls. Also pure tones with frequencies between 20 Hz and 6 kHz at levels below 100 dB could not generate reactions above level one.

Very high ultrasonic levels of 135 dB at frequencies between 18 kHz and 50 kHz did not produce any reaction.

Only pure tones above 100 dB produced strong reactions of the gulls initially (fig. 4). But the birds soon got used to these signals and showed only week reactions even at high sound intensities.

In summary, the following signals were inefficient:

- Infrasound and normal sound at low frequencies
- Pure tones in the normal hearing range
- Ultrasound
- Amplitude-modulated pure tones (AM)
- Noise Signals (Bandpass noise)

5.3 Sound signals for efficient scaring

Strong reactions were observed with frequency-modulated signals. The strength of the reaction was influenced by the parameters:

- Starting frequency f_o
- Frequency span (Bandwidth) B and
- Modulation frequency f_m

A large variety of combinations between these parameters was shown to be effective. Good efficiency with reaction levels of 5 and 6 was found in the following intervals:

$$f_o = 200 \text{ Hz}$$
$$0{,}5 \text{ Hz} < f_m < 20 \text{ Hz}$$
$$2 \text{ kHz} < B < 7 \text{ kHz}$$
$$2 \text{ s} < \text{Duration.}$$

With efficient signals, the gulls reacted within two seconds, but at reaction levels below or equal to four they reacted only within ten seconds. Finally, a signal duration of 20 seconds was chosen. With this signal, returning gulls were scared away for a second time, but adaptation to the signals did not occur.

6 TECHNICAL CONCEPT

A group of effective frequency-modulated sound signals with the following properties was selected:

- Frequency span more than 4 kHz
- Modulation frequency between 0,5 Hz and 20 Hz.

These signals proved to be effective also on a waste dump during a period of more than one month. Sound pressure levels down to 60 dB at the birds ears were shown to be effective. An electroacoustic device constructed on this basis consists of a rugged waterproof housing and radiates the sound with a preselected radiation pattern (fig. 5). It has the following properties:

- Battery-powered with low current consumption.

- Automatic and manual trigger.

- Preselectable signal types and duty cycles.

- Maintenance-free operation for one week (running at ten minute-intervals).

- Automatic variation of scaring sounds.

- No mechanical wear off.

- Adaptable to different bird species.

- Fitting to triggering sensors.

Additional experiments on a waste deposit revealed the following observations:

- At high noise exposures (85 dBA) from the environment, the active area was restricted to a radius of 30 meters.

- When the scaring sounds were directed to incoming flocks of birds, they fled away from the sound source: The birds stayed away for 20 seconds up to 15 minutes.

- In quiet surroundings, the typical diameter of effective operation was between 200 m and 400 m.

- When the birds were insonified at their roosting places, they showed very strong flight reactions and stayed away for more than one hour (fig. 6).

- Negative effects on working personnel and on animals in the surrounding areas were not observed. The signal types (250 Hz - 5000 Hz, 90 dBA during 20 s at 10 m distance) are tolerable in working areas.

7 DISCUSSION

In a systematic study it was shown that inaudible sound for humans is also inaudible for birds. The hypothesis of hearing at infrasonic or ultrasonic frequencies in birds must be negated.

The hearing threshold curve of gulls has proved to give a good estimate for the scaring efficiency of wideband sound signals. In additional behavioural experiments, a group of frequency-modulated sound signals with strong scaring effects was identified. They were effective for roosting birds down to sound pressure levels of 60 dB. Not only gulls, but also swarms of starlings were scared away by the signals.

An electroacoustic device was developed on the basis of these results. It is suited for the operation on airfields against incoming and roosting birds. It can be triggered automatically, by radio signals or by bird sensors. Without operator interaction, the device is operable for least one weak, then the batteries should be recharged.

Circular and asymmetric sound beams can be radiated depending on the loudspeaker arrangement. A test on an airfield has been started, but additional experiments on traffic airports are required.

8 LITERATURE

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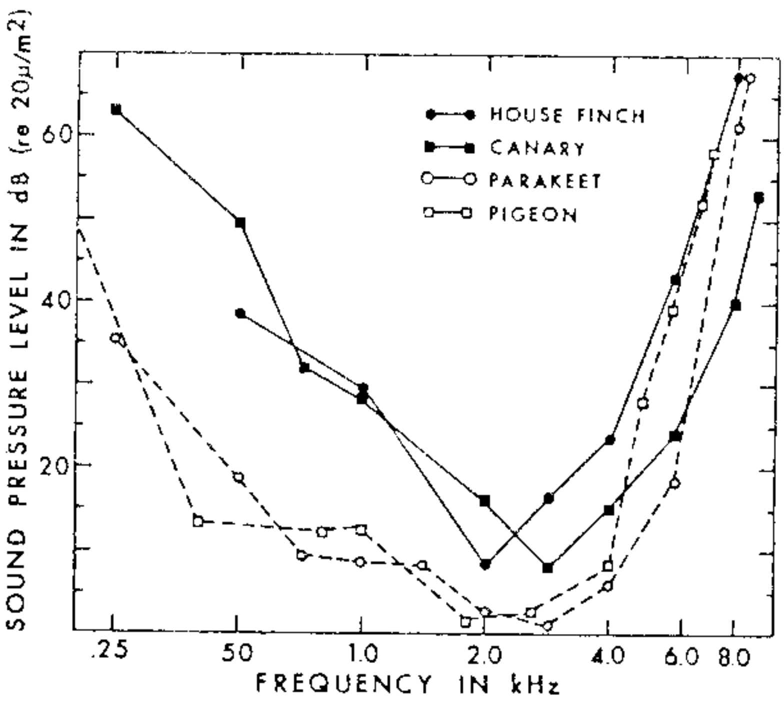
FIGURE 1: Auditory threshold curves in birds and small mammals /4/



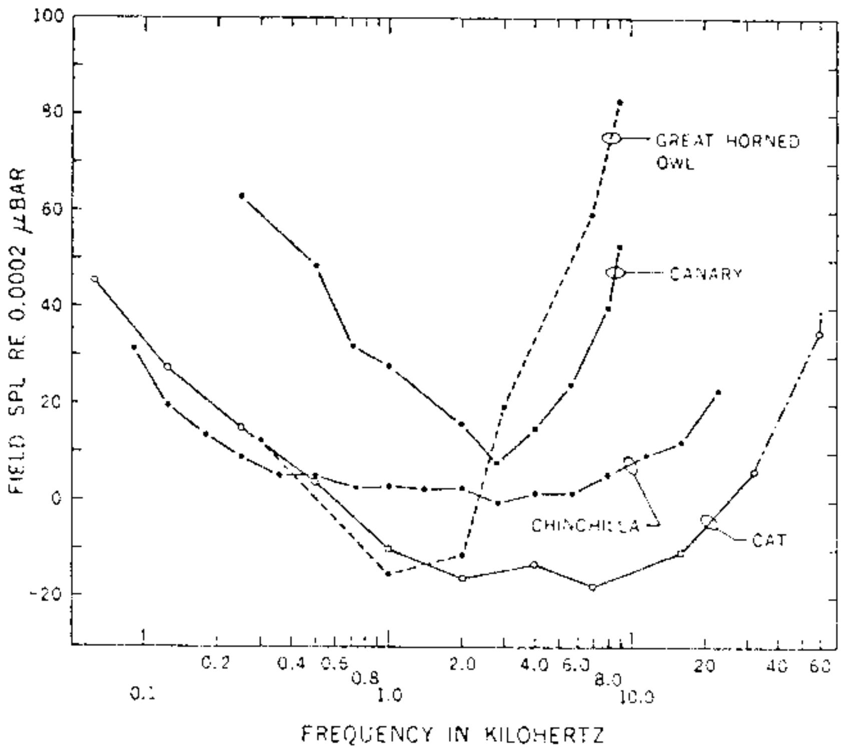


FIGURE 2: Auditory threshold curve in man

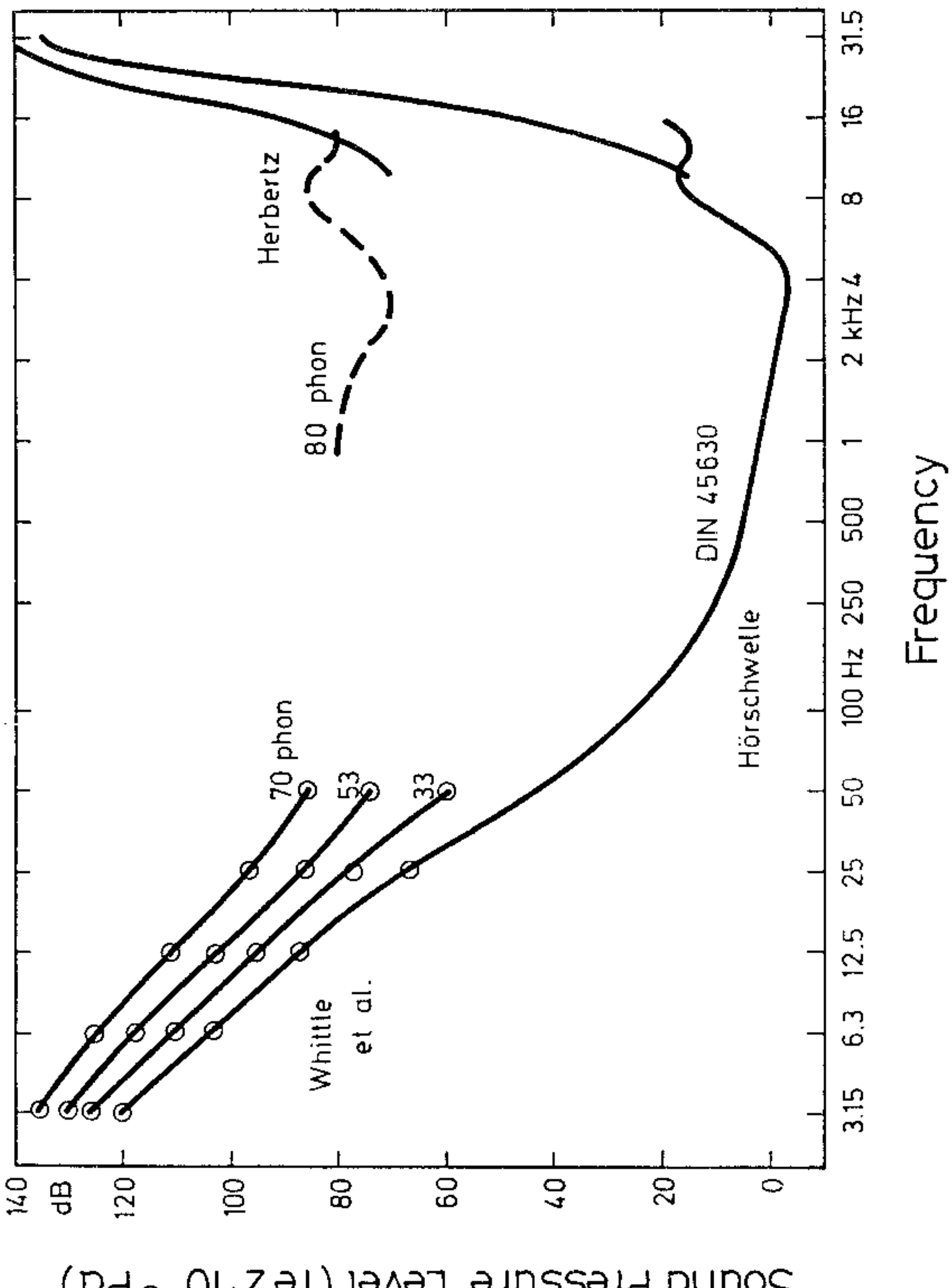


FIGURE 3: Hearing threshold in gulls (●) pigeous (♦) and gunea fowls (O) determined by electrophysiology

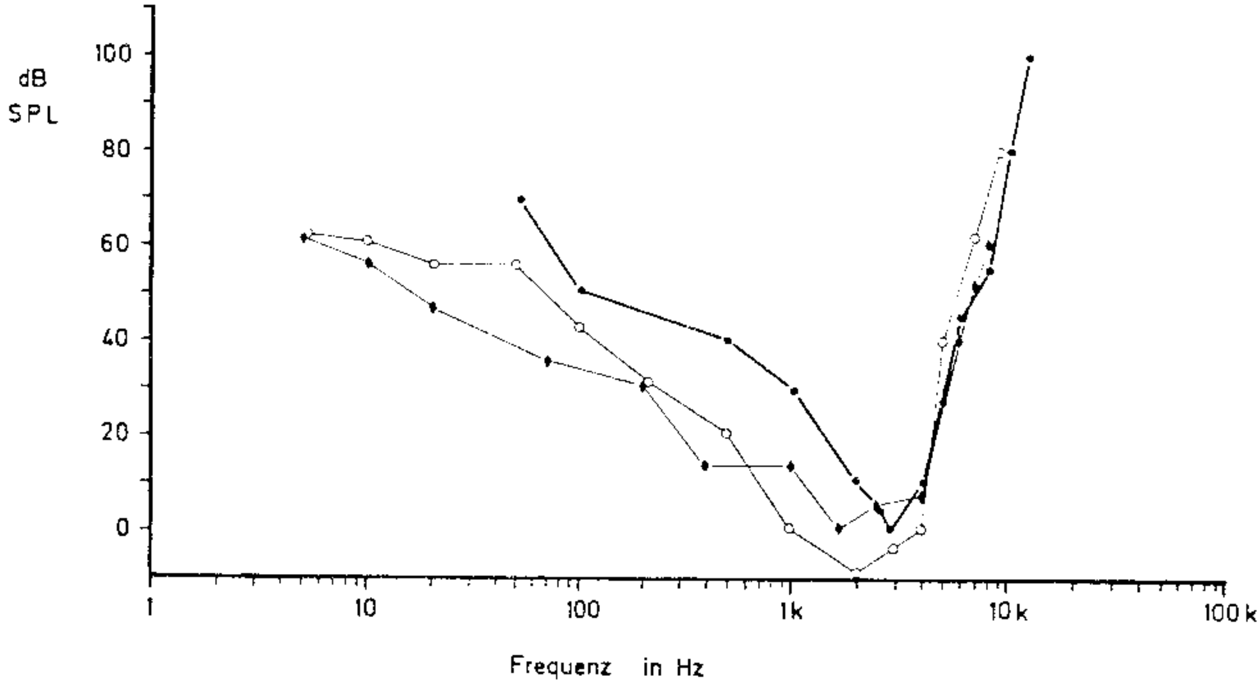


FIGURE 4: Reaction level of gulls for tones at 100 dB sound pressure level

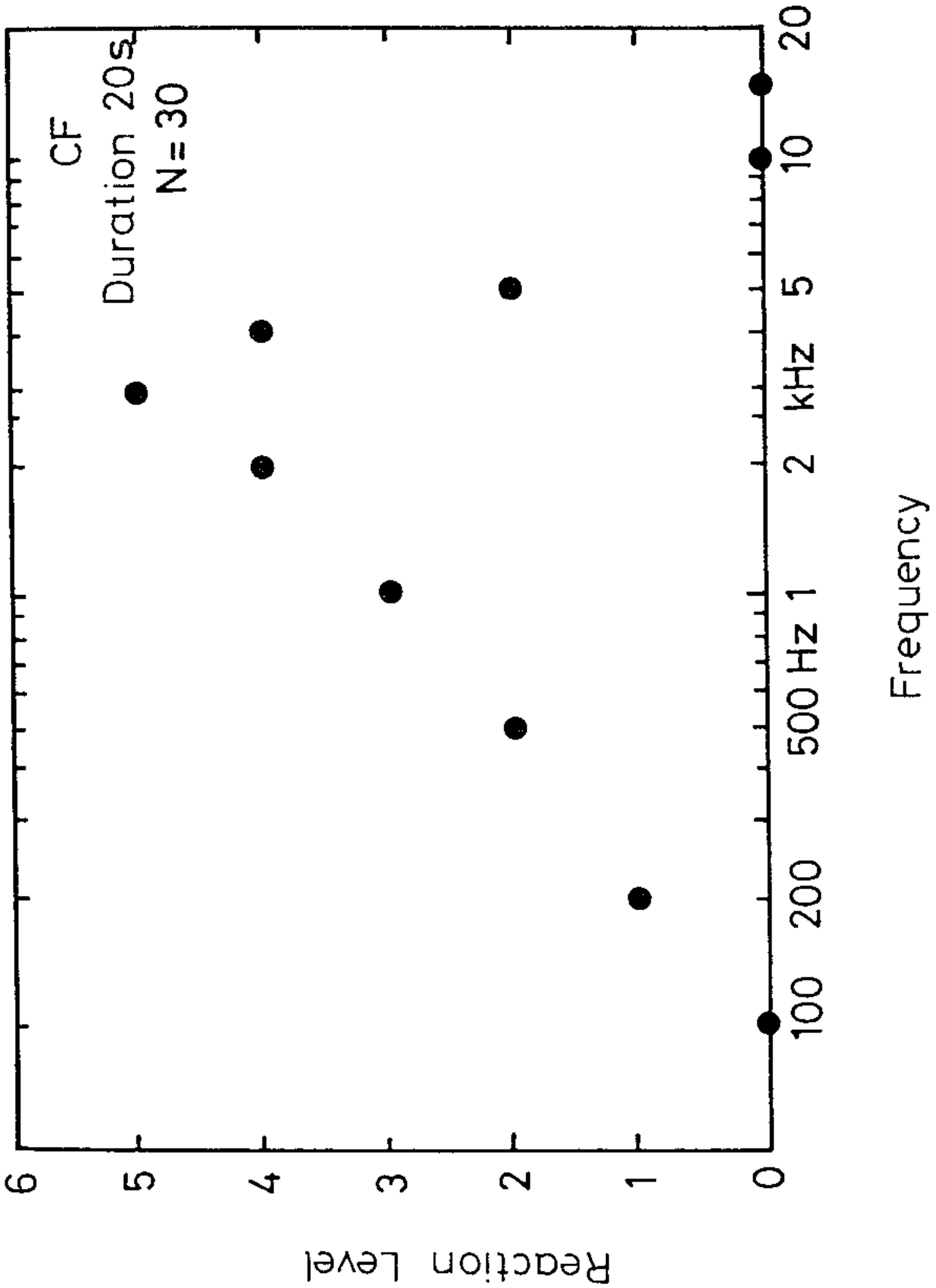


FIGURE 5: Electroacoustic bird scaring device

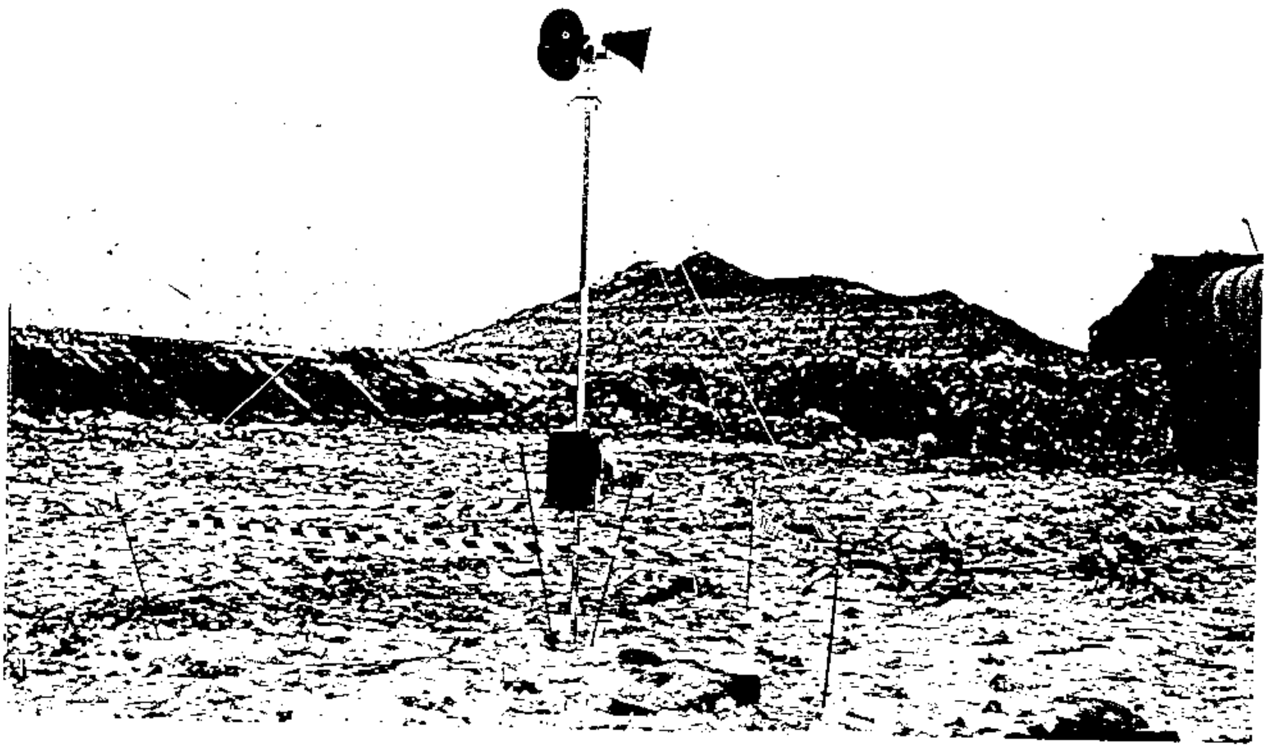


FIGURE 6: Effect of scaring sounds on roosting gulls. Pictures taken before and short time after insonification