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DEEP WATER RECORDINGS OF PINNIPED SOUNDS,(U)
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Addendum to Proceedings[1]

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DEEP WATER RECORDINGS OF PINNIPED SOUNDS

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Aspects of pinniped sounds have been reported by many authors (Wilson, 1907; Lindsey, 1937; Schevill, et al, 1963; Poulter, 1963; Evans and Haugen, 1963; and others). The purpose of this paper is to discuss occurrences of sounds, presumably from pinnipeds, in Southern California waters. The presumption of source is based upon (1) the characteristic mammal-like quality of the sounds, (2) the abundance of California sea lions, Zalophus californianus, in the area of study, (3) the barking heard in air on shore nearby and both in air and water with sea lions swimming nearby at B (Fig. 1), and (4) the similarity of the sounds to identified pinniped sounds recorded on tape.

Methods. In July 1963 a series of sound transmission tests was made off San Clemente Island using three hydrophones at separate locations and explosive signals from a distant source (Wenz, et al, 1965). One hydrophone was bottom-mounted near shore at 60 fathoms (hydrophone S, Fig. 1). Another hydrophone (D, Fig. 1) was bottom-mounted four miles seaward from hydrophone S at 450 fathoms. A third hydrophone

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[1] Addendum to the Proceedings of the Second Annual Conference on Biological Sonar and Diving Mammals
17 and 18 May 1965, Stanford Research Institute, Menlo Park, California

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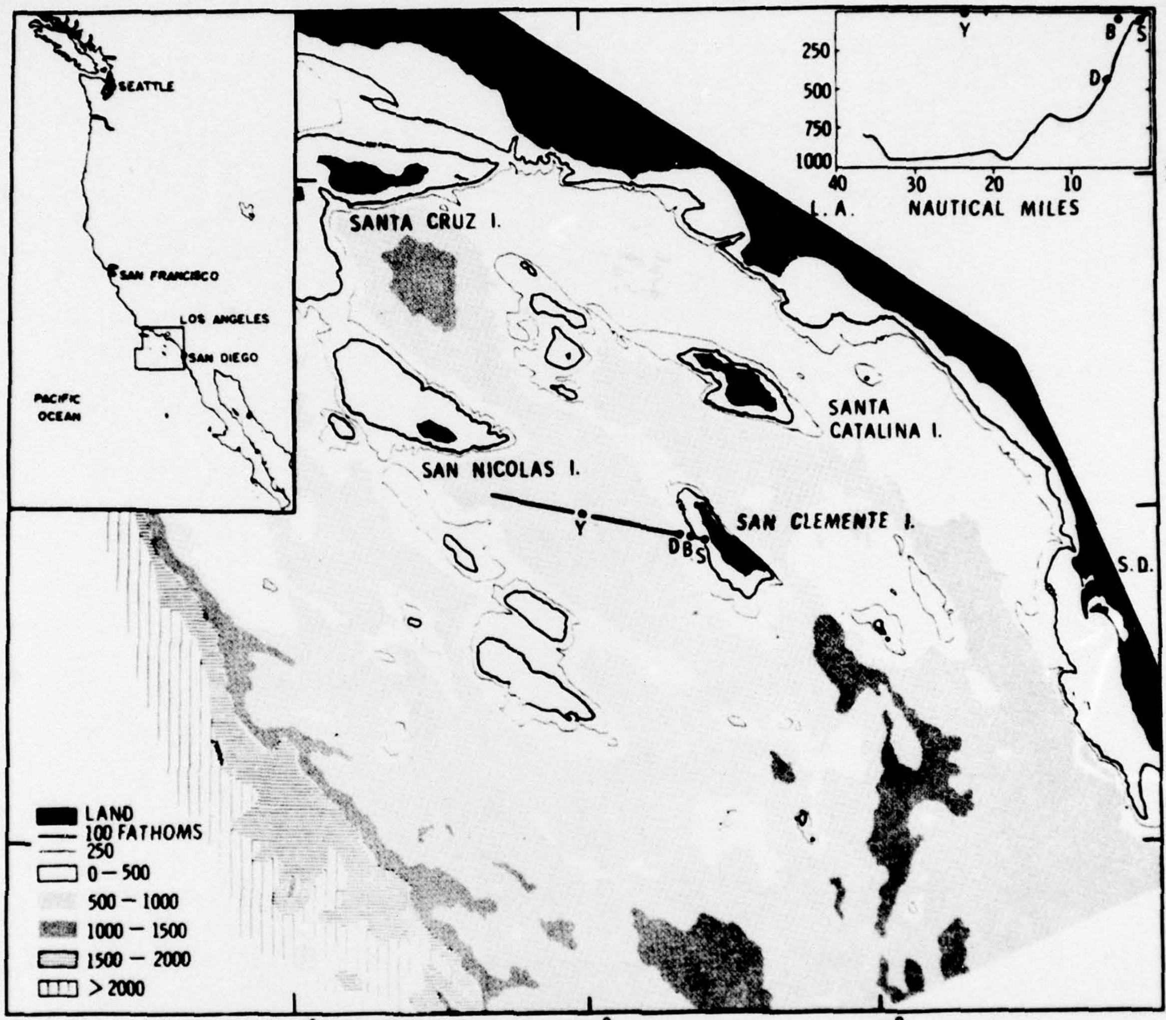
Fig. 1 Chart showing the area of study and position of hydrophones off San Clemente Island.



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(B, Fig 1) was suspended from a vessel. B and vessel Y do not bear directly on the data reported here; however, their application to other work has been described (Wenz, et al, 1965). Hourly samples of ambient noise were recorded during 8 days of sound transmission tests. Numerous biological sounds contained in these samples were classified and enumerated. Diurnal variations in their occurrence helped explain changes in ambient noise levels (Thompson, 1965). This report primarily concerns characteristic pinniped-like barks, a prevalent component of the recorded biological sounds.

Sound analyses were made with a Kay Vibralyzer set up for an effective filter bandwidth of 20 Hz, a Brüel & Kjaer one-third octave band analyzer, and a Tektronix storage oscilloscope. One-third octave band levels were read from Sanborn level recorder charts. Playback from a Magnecord 748 tape recorder was monitored using a MacIntosh 50-watt amplifier and an Altec speaker system.

Results. Barking was present in every hourly sample from hydrophones D and S. Other pinniped-like sounds resembling snorts, chuckles, and growls were frequently recorded from hydrophone S but were uncommon at hydrophone D and are not included in the scope of this report. Representative samples of barking from hydrophone S (Figs. 2a, b, c) indicated that the barking signals were quite varied in harmonic emphasis and in degree of frequency modulation within an individual bark. One characterictic frequency modulation pattern was U-shaped when displayed by sound spectrogram (Fig. 2b). As at hydrophone S, the barking received at hydrophone D consisted of many frequency-time patterns; as shown in Fig. 2d, one common pattern was strong around 1000 Hz and had little frequency modulation.

Fig. 2a. Sound spectrogram of three barks (A, B, C) received by hydrophone S. These barks have greatest strength in the fundamental and second harmonics. A snort (D) follows the barking sequence. The effective width of the analyzing filter for this spectrogram and those that follow was 20 Hz.

Fig. 2b. Sound spectrogram of five barks received by hydrophone S clearly showing U-shaped frequency modulation with strong second and third harmonics.

Fig. 2c. Sound spectrogram of barking received by hydrophone S with no evidence of U-shaped frequency modulation.

Fig. 2d. Sound spectrogram of barking received by hydrophone D. The second harmonic exhibits considerably more strength than the fundamental.

FIG. 2a

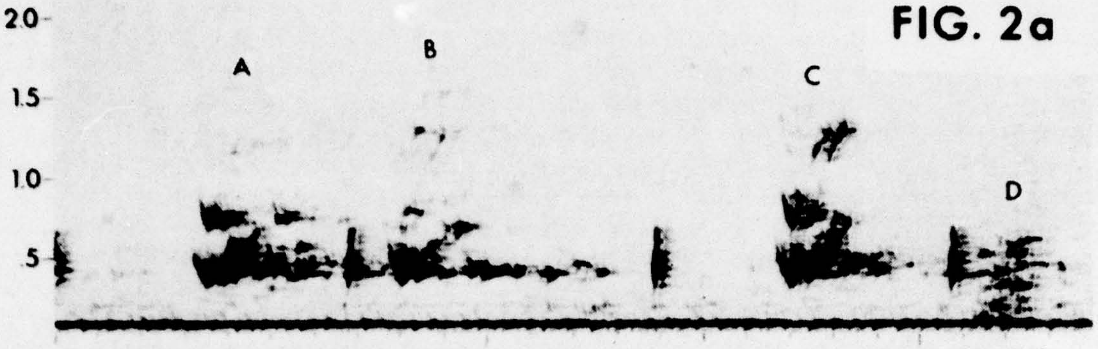
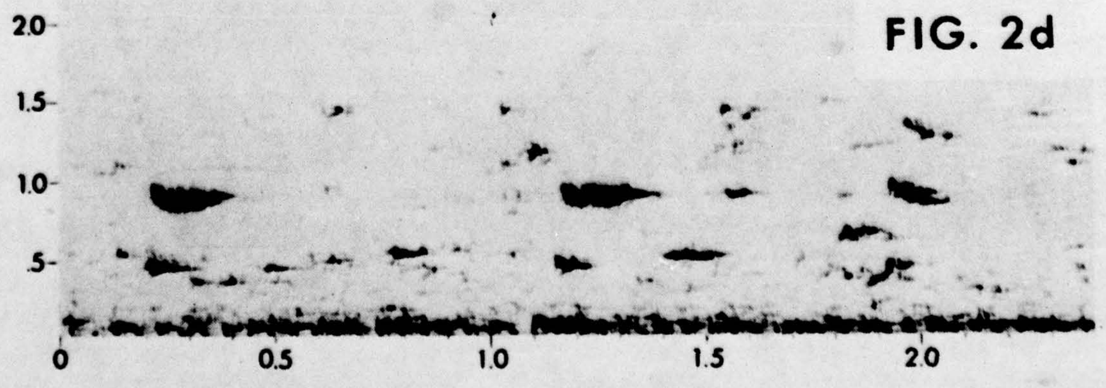


FIG. 2b

FIG. 2c

FIG. 2d



The frequency spectrum of a particular barking sample sometimes was wide (Fig. 2a, b, c, and Fig. 3) and sometimes concentrated so much that its over-all sound pressure level was determined by the component within one-third octave band (Fig. 2d).

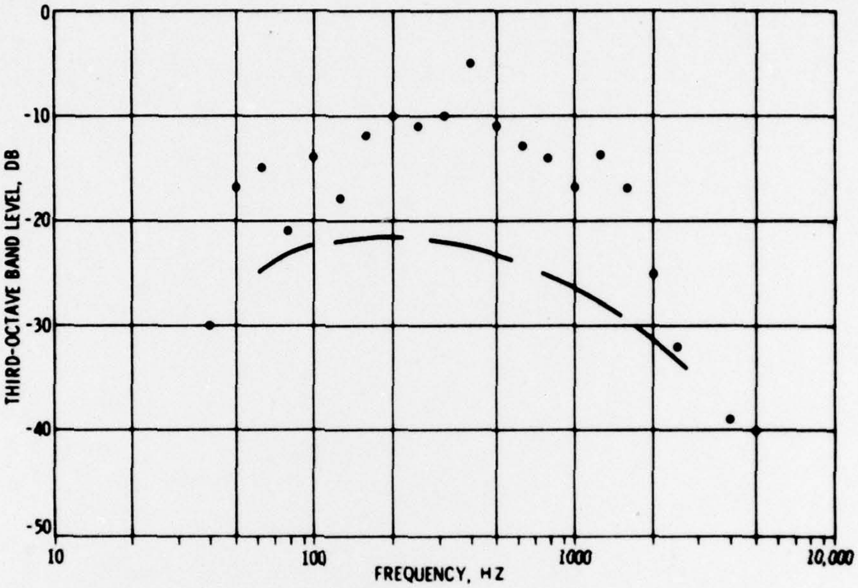


Fig. 3 Spectrum plot of a short segment of one bark illustrated in Fig. 2a. The data points are for third-octave bands centered at frequencies plotted. The dashed curve is approximate background noise level.

Fig. 3 shows third-octave analysis of one of the barks shown in Fig. 2a. Its relatively great frequency extent and lack of definite resonances or harmonic peaks is probably due to frequency modulation within the bark. The characteristic amplitude modulation of a bark was teardrop shaped (Fig. 4). The duration of a bark varied from a little over 100 msec, as shown in Fig. 4, to approximately 300 msec.

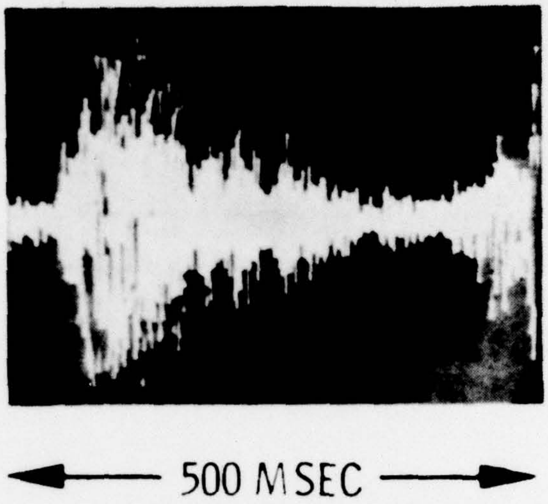


Fig. 4 Oscillogram of bark illustrated in Fig. 3.

Analysis of barking sound pressure level by hydrophone and hour was performed in the third-octave bands centered at 500 Hz and 1000 Hz. When strong barking was present, the barks always showed up strong in one or the other of these frequency regions (usually both).

The main results are based on measurement of maximum sound pressure level during a sample period. From these data the maximum value occurring during the 8-day period, for each hour of day, was determined (Fig. 5). All values were converted to relative sound pressure level so that OdB refers to the same absolute level regardless of which hydrophone or frequency band is considered. Of the 48 level values for each hydrophone (24 hours, 2 frequency bands) the median for hydrophone S was 19.2 dB and that for hydrophone D was 22.2 dB. The highest barking level observed was 32 dB for bark signals from hydrophone S at 1500 hrs. This was 5 dB higher than any bark signals from hydrophone D.

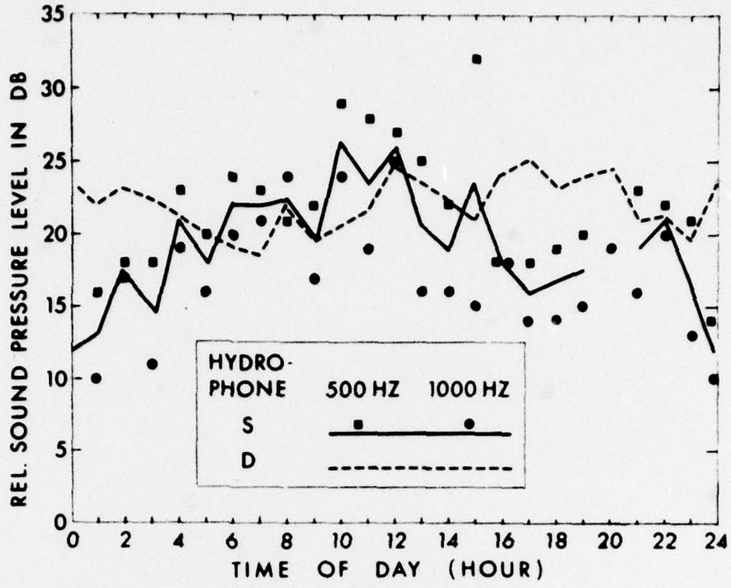


Fig. 5 Plot of maximum relative sound pressure level of barking signals by time of day. The filled squares and circles are for hydrophone S levels in third-octave bands centered at 500 and 1000 Hz; the solid line is plotted midway between these datum points. The dashed-line curve is for hydrophone D maximum barking leveles and is an average of the levels third-octave band centered at 500 and that centered at 1000 Hz. The datum points associated with this curve are not plotted. A break in the curve for hydrophone S is present at 2000 hrs because other intense biological sound in the 500 Hz region make measurement of barking level questionable at this hour. When bark signals were less than 9 dB above background noise, corrections were made for contribution of noise to signal (Young, 1955).

There was little if any diurnal trend in hydrophone D barking levels, but for hydrophone S diurnal trends were present, consisting of increased level from sunrise to mid-afternoon, another peak around 2000 to 2200 hrs, and a reduction during the middle of the night. The median level in the third-octave band at 500 Hz was higher than for the band at 1000 Hz , the difference being 5. 5 dB for hydrophone S and 1. 5 dB for hydrophone D. While in the hydrophone S data superiority in level was noted for the band at 500 Hz for all 24 hours (Fig. 5), in the hydrophone D data there were 10 of 24 hours during which the maximum values occurred in the 1000 Hz region.

Discussion. (1) Although diurnal trends are questionable in the hydrophone D data, a study of Fig. 5 suggests that at times of day when barking levels are lowest for hydrophone S, they are among the highest for hydrophone D. This effect is present in the early evening and again from 2300 to 0400. Not enough is known of the pinniped behavior and activity in these areas to permit speculation as to possible relationships of variation in barking level by hour at the two hydrophones.

(2) A surprising result was that, although some bark signals received from hydrophone S were 5 dB higher than any received from hydrophone D, maximum sound pressure levels received from 2700 ft depth by hydrophone D averaged 3 dB higher than those received from 360 ft depth by hydrophone S. If assumptions are made that (a) barking pinnipeds were widely distributed on the surface off the west shore of the island, (b) that maximum levels were received when the sources were almost directly over the hydrophones, and (c) that propagation in both cases was strictly determined by spherical spreading losses, the levels at hydrophone D would be expected to be 18 dB lower than those at hydrophone S. That hydrophone S levels were not superior could be explained by assuming the sources were barking underwater and dived closer to the deep hydrophone. The question of whether pinnipeds bark underwater has been controversial among bio-acousticians. More recently, underwater barking by sea lions in a tank was reported by Schusterman, et al (1965). Unfortunately, not enough was known about pinniped activity close to hydrophones S and D to do more than speculate. Many variables need

further investigation, including source level measurements from pinniped populations,[1] level variation among individuals, and within same individual according to emotional state, source level of underwater barks, possible effects of depth on barking source level and frequency spectrum, the efficiency of coupling barks from throat to water, previously mentioned by Wenz (1964), population movement behavior, and various oceanographic variables which might have affected reception at hydrophones S and D differentially.

(3) The secondary peak in barking level between 2000 and 2300 hrs at hydrophone S coincided with a period of high-level biological noise that has been referred to as Click Chorus (Wenz, et al, 1965; Thompson, 1965) and which was a main factor in the 200 to 1000 Hz sound pressure level from 2000 to 0400 hrs. Traces of barks during this period naturally did not rise above the background noise nearly as much as during other periods, but, where required throughout the data, corrections were made for contribution of noise to signal level, as outlined by Young (1955). At 2000 hrs Click Chorus typically caused a 15 to 20 dB rise in 500 Hz background level and completely obscured the barking signal traces in this frequency region. By 2100 hrs Click Chorus level was diminished enough to permit

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[1] Rough source-level measurements were obtained on two California sea lions in a pool at the San Diego Zoo. The barking was recorded from a hydrophone and a microphone simultaneously while the animals were swimming at the surface. Source distance and movements were described on the microphone channel along with the barks. The sound pressure level re 0.0002 μbar for each was figured to be 125 dB. Measurement precision was not obtained for several reasons. The greatest reason was that the hydrophone sprang a leak and was put out of commission just as it was to be calibrated. Of interest was that the received levels seemed to follow closely the principle of 6 dB attentuation of signal per distance doubled.

good approximations of signal level, even though barking levels were diminished at and just after midnight.

(4) Also of interest is the fact of receiving barking essentially continuously, hour after hour for eight days, from a hydrophone bottom-mounted more than four miles from shore and at a depth of 2700 ft. Recently, Watkins (1965) recorded pinniped sounds under Antarctic ice from an array of hydrophones suspended as deep as 300 m (about 984 ft). Continued studies such as these should clarify the nature of pinniped sounds received in the ocean depths.

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