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Underwater Sound Production by Captive California Sea Lions, *Zalophus californianus*

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(Plates I-V)

INTRODUCTION

THUS far, it has been shown that the California sea lion, *Zalophus californianus,* produces two types of underwater sounds —clicks, or short-duration sound pulses, and barks (Poulter, 1963; Schevill, Watkins & Ray, 1963). In contrast, the bottlenose porpoise produces a wide variety of sounds—clicks, whistles or squeals, barks (Evans & Prescott, 1962), and "cracks" (Caldwell, Haugen & Caldwell, 1962). Although the clicks are used for echolocation by the porpoise (Kellogg, 1961; Norris, 1964), there is evidence indicating that a variety of whistles have emotional and communicative significance. Some whistle contours and the cracking sounds have been said to be associated with distress or fright reactions (Caldwell *et al.*, 1962; Lilly, 1962).

Underwater clicks by *Zalophus* have been reported to occur usually when an animal was in the final stages of searching for food (Poulter, 1963; Schevill *et al.,* 1963) or for an object signalling food (Evans & Haugen, 1963; Schusterman, 1966). Most of these tests have limited the range of behavior to those involved in feeding activities. In order to determine whether *Zalophus* is capable of emitting a greater variety of underwater signals and calls than had been previously reported, several California sea lions were monitored while swimming freely under a number of stimulus conditions.

PROCEDURE AND APPARATUS

All observations and recordings were made while animals were swimming untethered in an oval tank constructed of redwood, measuring 15 feet by 30 feet and 6 feet deep, and filled with 82 kiloliters of fresh water. Recordings of the underwater sound productions by *Zalophus* were made under the following conditions: (a) conspecific social interaction; (b) orientation to a mirror; (c) fleeing from a human observer.

Underwater sounds were continuously monitored by a Channel Industries 275 hydrophone (20 Hz to 150 kHz) and an Ampex 2044 amplifier-speaker system (65 Hz to 13 kHz). Vocal signals were periodically recorded on a Uher 4000-S tape recorder at 7.5 inches/second (40 Hz to 20 kHz).

Spectographs of the evoked signals were made, using the Kay 661 sonograph. Either of two analyzing bandpass filters (narrow or wide) may be used with the Kay sonograph. The wide-band filter has an effective bandwidth of 300 cycles, and the narrow-band filter has an effective bandwidth of 45 cycles. The analysis used is indicated on each of the spectrographs presented. The use of this method for the analysis of biological sounds has been described by Borror (1960).

RECORDED SOUNDS

Clicks.—Our preliminary analysis indicates that *Zalophus* produces a great variety of click patterns. Although most of the click trains have a duration of 2 seconds or less, many trains last as long as 23 seconds with pauses of less than 0.5 second. The click repetition rate may vary from less than 5 per second to 70 or 80 per second, all within a given click train (separation between clicks of 0.5 second or less).

Plate I is a spectrograph of clicks produced by one sea lion while play-fighting with another sea lion. When the tape which produced this spectrograph was replayed, we noted that a popping sound seemed to be superimposed on the clicks. This is indicated on the graph, we believe, by the great variation in the frequency pattern. Such a sound pattern is highly distinctive and has been produced by only one of the animals (Cathy).

It is important to note that clicking sounds were never emitted at fairly regular intervals by any of the animals under any of the free-swimming conditions. This is in marked contrast to the behavior of the bottlenose dolphin, which is reported to emit "exploratory" pings every 15 to 20 seconds. Such periodic signal emission has been suggested as the sonar equivalent to "glancing" in the field of vision (Kellogg, 1961).

Barks.—This form of underwater vocalization has most of its energy below 3500 Hz, although some energy may be found at frequencies as high as 8000 Hz. There is little variation in the duration of any given bark; they generally last from 200 to 300 milliseconds. Barks are sometimes preceded by a series of clicks, as shown in Plate II. The sounds shown in this plate were produced by a two-year-old male *Zalophus* while it was fleeing from the experimenter, who was attempting to drive the animal out of the testing tank. During the experimenter's initial attempts, the animal swam rather rapidly while producing long trains of clicks. As the action became more intense, the clicks shifted into a series of barks.

Whinny.—A spectrograph of this vocalization is shown in Plate III. It was frequently produced by a 3.5-year-old female *Zalophus* (Bibi) during an aggressive encounter. For lack of a better term, we have called it the "whinny" sound, since it sounds a little like a horse neighing. This vocalization is often preceded by clicks or a growl sound. The whinny sound typically lasts for about 1.5 seconds and may be repeated three or four times in succession. This whinny sound may be the female counterpart of a male bark. However, contrary to another report (Bonnot, 1951), we have heard females bark both in air and submerged.

Buzzing.—A characteristic "buzz" sound from a sea lion in a social situation is depicted in Plate IV. This vocalization may actually be a series of discrete sound pulses which occur so rapidly that they take on a buzzing quality.

Bang or Crack.—This sound has thus far been produced by two of our California sea lions (a male and female). The sound was first heard when Bibi was confronted with its mirror image and was repeated several times over a period of days, usually under the same circumstances. Plate V shows a pair of these high-energy "bang" sounds. The sound, which has always been associated with extremely rapid swimming, appears quite loud and mechanical to the human ear, and, as the spectrograph shows, it is a broad-band pulse with a rapid onset. Apparently, from the description of Caldwell *et al.* (1962), *Zalophus'* "bang" sound is very similar to high-energy "crack" sounds produced by *Tursiops truncatus* under conditions of fright. We have recently heard similar sounds produced by Steller's sea lion *(Eumetopias jubatus)* while performing on an underwater visual discrimination task.

Sound Production Mechanisms

Careful observations of *Zalophus* while it was in the act of emitting underwater clicks have indicated some movement in the area of the throat or larynx; such movement appeared less pronounced when the animal was silent. These preliminary observations implicating the laryngeal area as the underwater sound-producing site of *Zalophus* have been supported by experimental evidence (T. C. Poulter, 1965). Using a triangulation technique, Poulter found that the site of underwater barking was the vocal cords on the anterior portion of the larynx and that the apparent point of origin of underwater clicks was posterior to the vocal cords.

All of the underwater vocalizations that have been described can apparently be produced with the mouth and nostrils closed and therefore without the emission of bubbles, or with the mouth and nostrils partially opened and with the emission of bubbles. Moreover, clicks may be produced in air with the mouth closed or with the mouth wide open. Barking sounds seem to show the same basic frequency-intensity structure in air and under water. However, clicking in air is usually less intense and much less frequent than under water. Although no systematic attempt has yet been made to measure the intensity of *Zalophus'* underwater clicks, there has been no difficulty in monitoring these sounds even when the background noise was considerable and the animal was as far as 5 to 6 meters from the hydrophone.

It is not clear how the "bang" sound of *Zalo-*

phus is produced, i.e., whether it is made by the sea lion's vocal apparatus, by jaw-clapping, or by some other mechanism such as the front flippers causing an underwater cavitation as they are thrust together and then parted during initiation of a very rapid swim.

Discussion

Thus far, all of the underwater sounds produced by captive California sea lions have had a pulsed structure and appear to be wholly or partly a function of social or investigatory responsiveness. The shifting from clicking to barking or to a whinny sound under conditions of either extra-specific or conspecific intimidation suggests that these calls form a single system of vocalization which changes as a function of the level of physiological arousal (Duffy, 1957), with barking indicative of a higher level of arousal than clicking. This notion is similar to that held by Andrew (1962, 1964), who has developed the concept of "stimulus contrast" to account for the vocalization of chicks and nonhuman primates.

Although there are certain similarities between the sonar signals of the porpoise (*Tursiops truncatus*) and the clicks of *Zalophus californianus,* there are also great differences. Whereas the clicks of the porpoise are very narrow columns of "noise" having their greatest energy up to 30 kHz, with components of lesser intensity reaching 170 kHz (Kellogg, 1961; Norris, 1964), those sampled from *Zalophus* thus far often contain at least traces of harmonics and have their greatest energy at 500 Hz to 4000 Hz, with possibly weak components extending to higher frequencies. Furthermore, regarding the porpoise, Norris reports that "during fine discriminations where sight is impossible, the environment is literally saturated with tiny plosive clicks, up to 500-600 per second," (Norris, 1964, p. 320). Such rapid pulsing has not been consistently produced by *Zalophus.*

Summary

Spectrographs are presented of underwater sounds made by captive sea lions (*Zalophus californianus*) under the following conditions: (a) social interaction; (b) orientation to a mirror, and (c) fleeing from the experimenter. These animals produce a variety of vocal utterances and sounds, including varying patterns of clicks, barks, "whinny" sounds, "bangs," and buzzes. All sounds thus far recorded and analyzed have a pulsed structure with dominant frequencies ranging from 500 Hz to 4 kHz. The sounds appear to be wholly or partly a function of the social and investigatory responsiveness of the sea lion.

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EXPLANATIONS OF PLATES

PLATE I.

Spectrograph of clicks emitted by a 3-year-old female California sea lion (Cathy) while play-fighting with another sea lion (narrow band).

PLATE II.

Spectrograph of clicks and barks produced by a 2-year-old male (Tommy) while fleeing from the experimenter (wide band).

PLATE III.

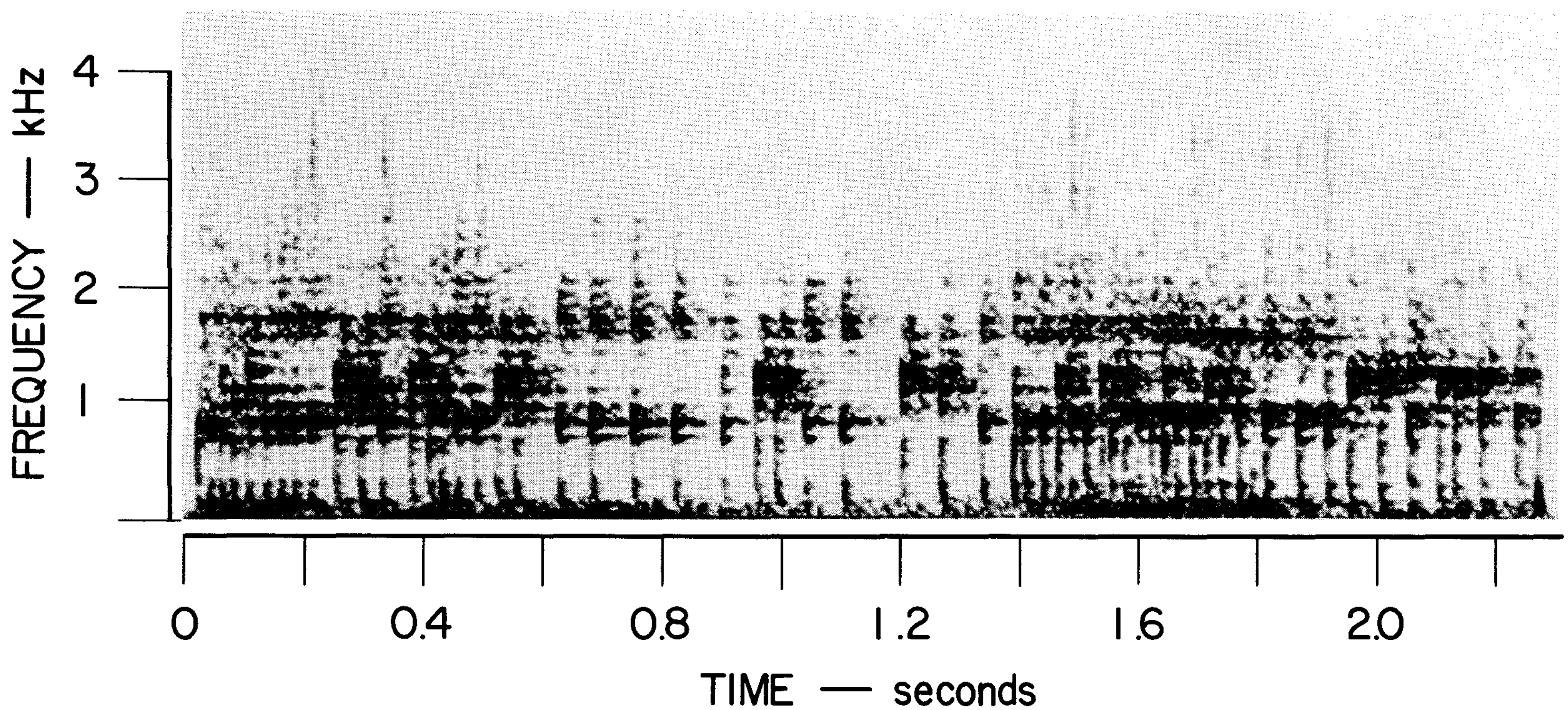
Spectrograph of Bibi's "whinny" vocalization produced during an aggressive encounter with another California sea lion (narrow band).

PLATE IV.

Spectrograph of a "buzzing" sound emitted by Cathy while swimming with another California sea lion (narrow band).

PLATE V.

Spectrograph of two "bang" sounds produced by a 3-year-old California sea lion (Bibi) while orienting to a submerged mirror.



UNDERWATER SOUND PRODUCTION BY CAPTIVE CALIFORNIA SEA LIONS
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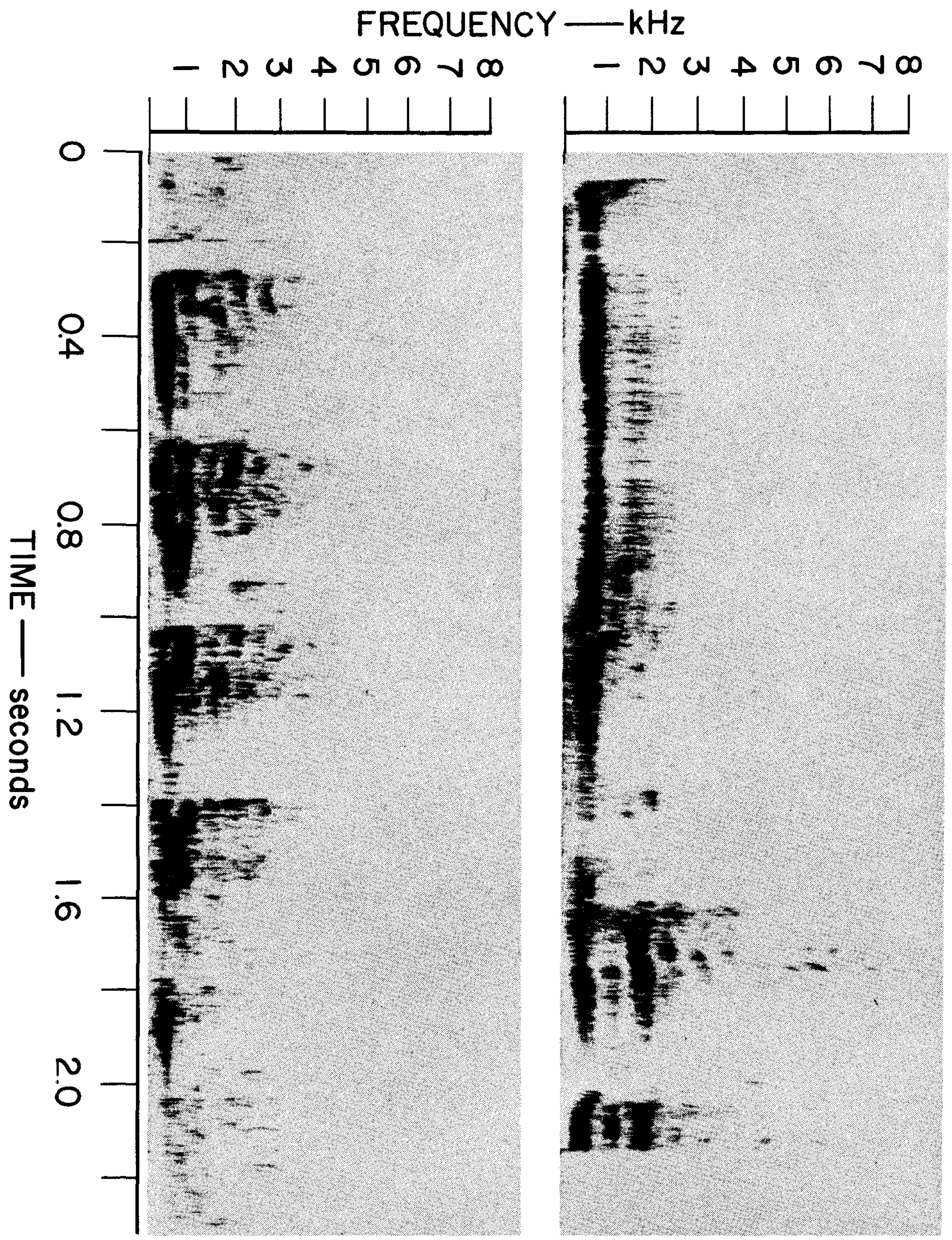

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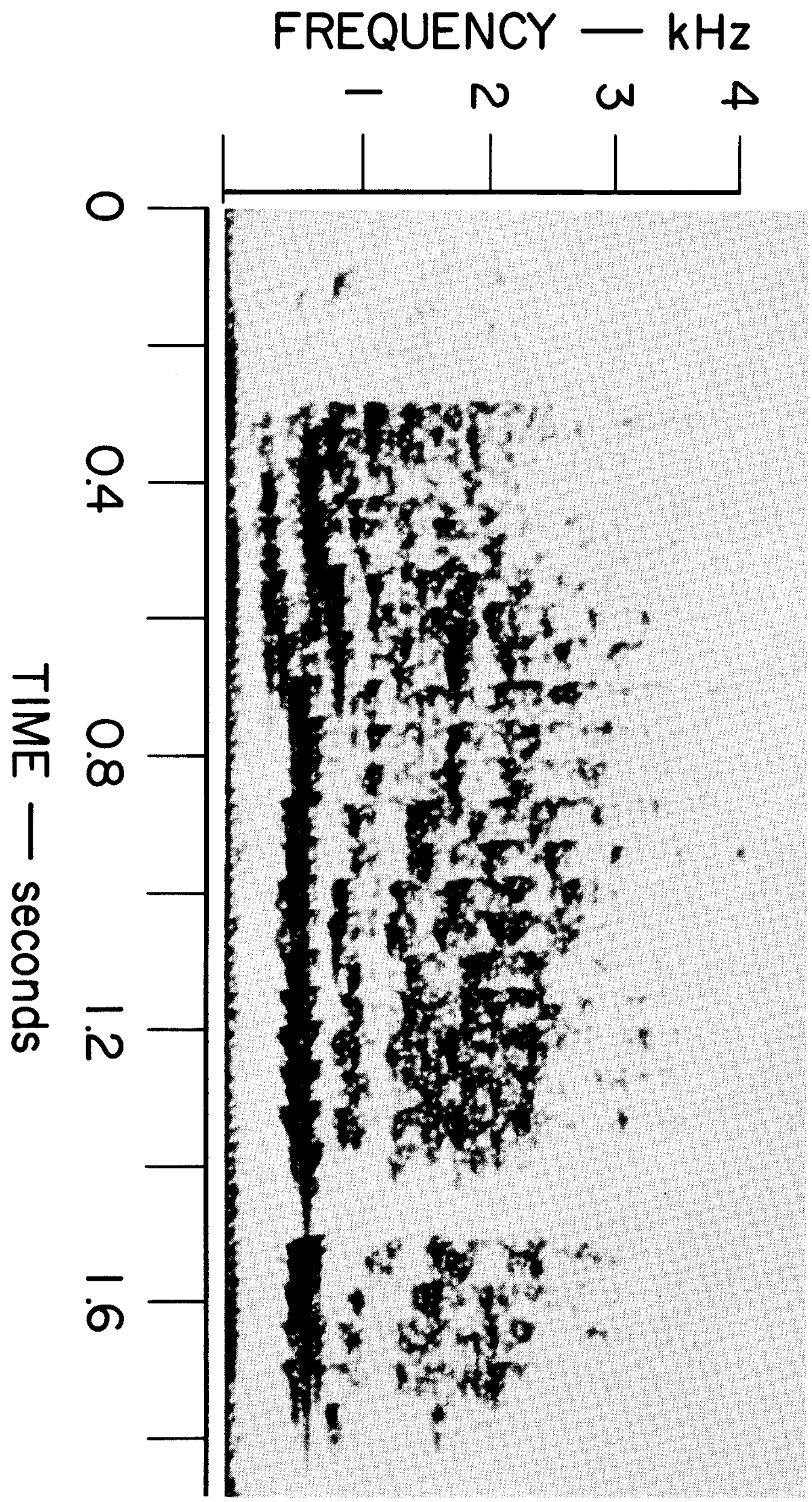

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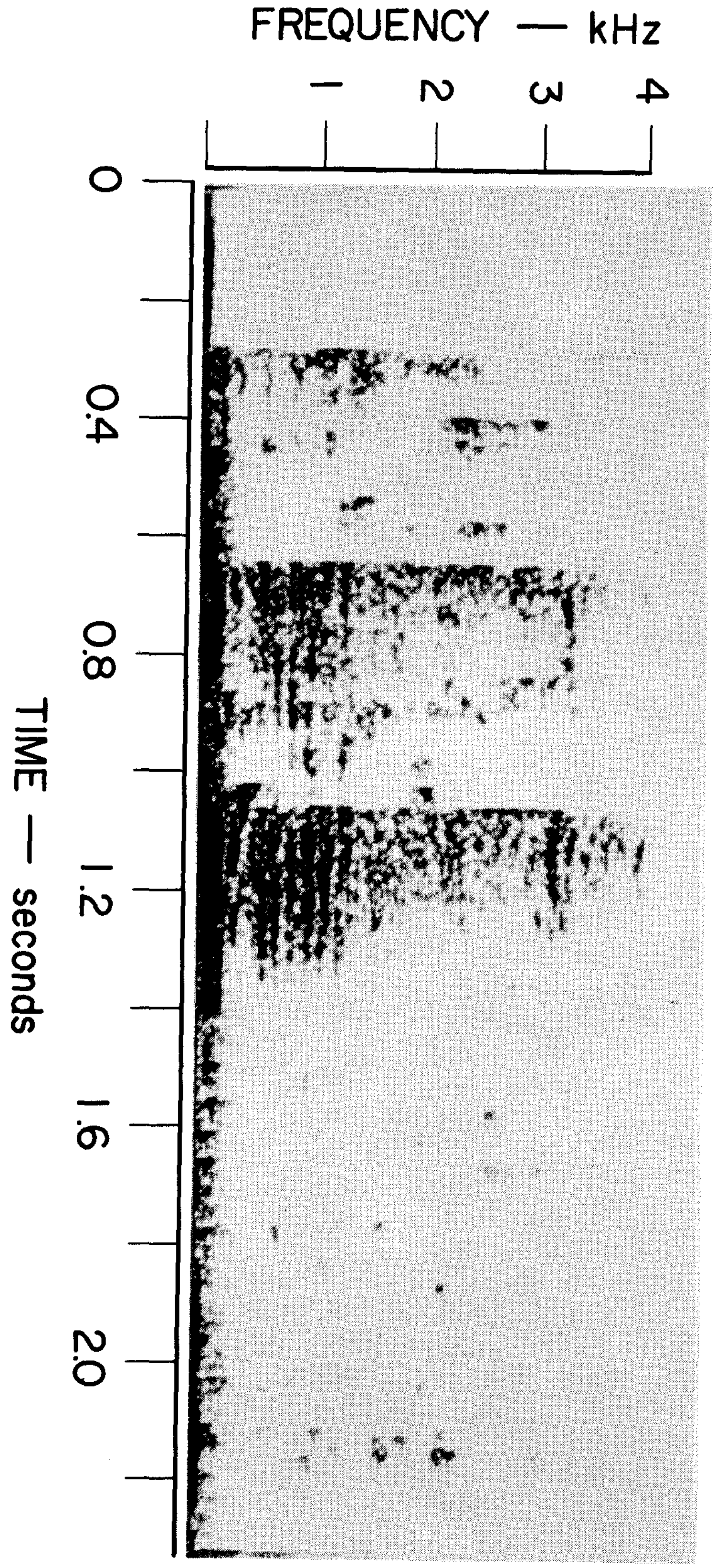

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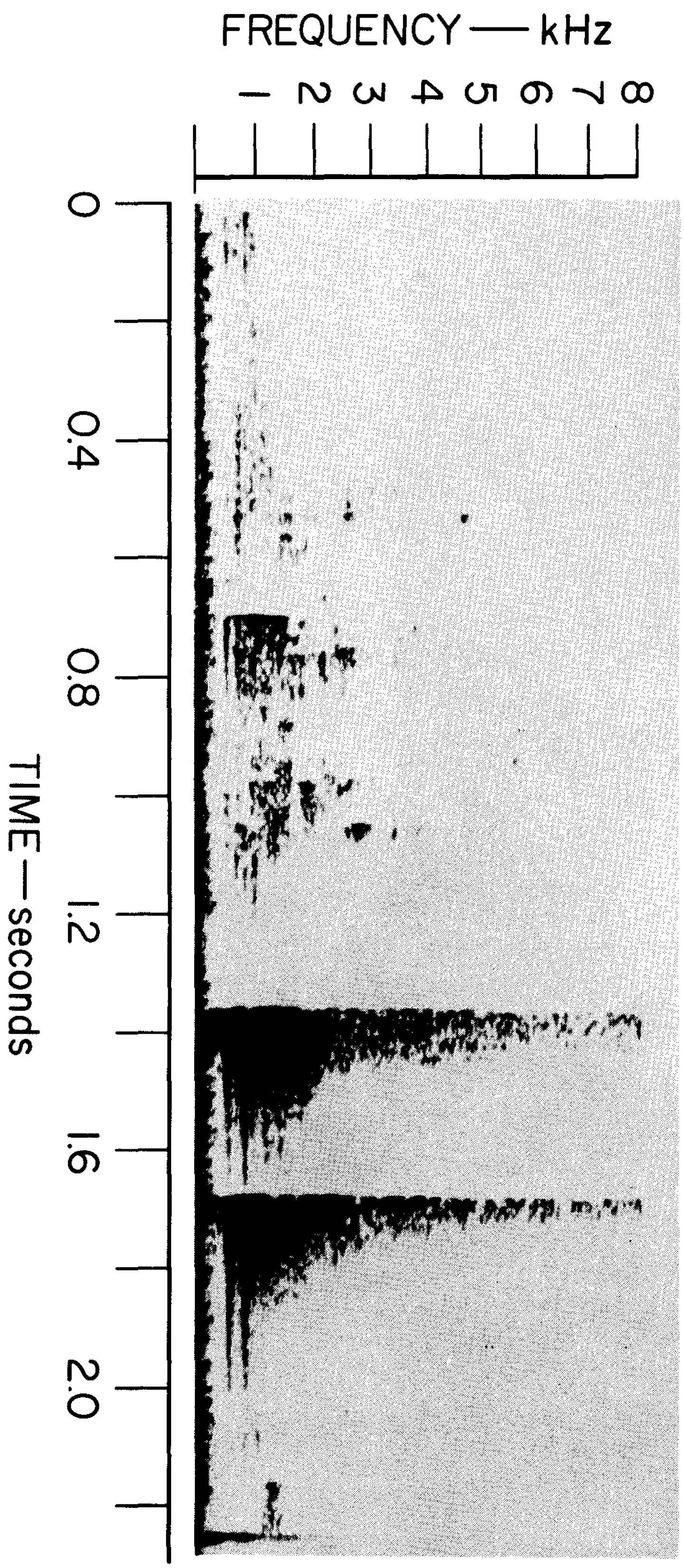

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