LONG-DISTANCE VOCALIZATIONS OF COYOTES (*CANIS LATRANS*)

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Abstract. --Evoked and spontaneous long-distance vocalizations of wild coyotes (*Canis latrans*) were studied in Texas and Oklahoma from June 1972 to August 1974. Sonagrams of tape-recordings showed that adult coyotes produced two basic sounds: the bark and the flat howl. These sounds were given by animals in both single and group situations. In addition the yip, yipe, short-howl, warble, laugh and irregular howl were common group vocalizations. Two or more sounds were often joined to form combination howls. The scream and gargle were characteristic of immature coyotes. Sound patterns from the bark to the flat howl formed a continuum of increasing phonetic complexity with intermediate sounds frequently produced. Coyote vocalization was variable in sound type, duration, Hz, amplitude of fundamental and other harmonics and in the sequence of combinations of two or more different sounds. In these ways information could be conveyed.

Social canids have a "rich repertoire" of sounds (Tembrock, 1963). Some types of canid vocalizations were discussed by Tembrock (1963, 1968), Scott (1968) and to a lesser extent by Huxley and Koch (1964) and Colby (1965). The most complete description of a canid sound was provided by Theberge and Falls (1967) for the howls of three adult Canis lupus, but interpretation and comparison of canid sounds has been hampered by lack of a description of the complete repertoire of a canid species.

The present paper describes types of coyote (Canis latrans) long-distance sounds and provides a first step for comparative studies of Canis vocalization now in progress. Most of the data were obtained from wild coyote populations in Webb and Duval Cos., Tex., 23-24 Aug 1973 and Welder Wildlife Foundation, San Patricio Co., Tex., 1 Dec 1972, 5-16 Feb 1973 and 15-18 Jan 1974. These areas were selected because hybridization with other canids was unlikely and for the abundance of coyotes. The time of the year in which these data were accumulated avoided the problem of distinguishing pups from adults, although coyotes less than a year old were certainly present. A considerable number of additional tape recordings of all coyote age groups from other localities in Texas and Oklahoma, obtained between June 1972 and August 1974, were available, but analysis of these recordings was not included because of the presence of pups, the problem of geographic variability and past, and in some cases, present hybridization with Canis rufus (McCarley, 1962; Paradiso and Nowak, 1971). This additional material, however, did confirm that major vocalization types were covered by the South Texas material. Because animals were seldom seen, any vocalization differences attributable to sex or size were, of necessity, ignored.

Methods

Coyote vocalization may be spontaneous or evoked by known auditory stimuli. Spontaneous sounds (as defined by Theberge and Falls, 1967) were recorded when and where possible, but this depended largely on chance and comparatively few spontaneous sounds were close enough for effective recording, although many were heard. Evoked vocalizations were secured at night using the techniques of Alcorn (1946) and Pimlott (1960). Coyotes were ordinarily stimulated by vocal imitations from my students or me because this was the fastest and most effective way to do it. If a response was not evoked by this method, amplified tape recordings or in a few instances a 12-volt burglar alarm type siren were used. Seldom, however, did these devices elicit a response when our vocal imitations failed to do so. After getting a response from one or more coyotes we generally moved to another area because getting subsequent responses from the same animals within a 10-20 minute period was not likely. (This lag period was similar to that reported by Pimlott [1960] for _C. lupus_). Whether or not this "lure" method (Moles, 1963) evoked mimic sounds was undetermined.

All responses were recorded at 19 cm/sec with Uher 4000-L tape recorders using Uher M-514 and M-516 microphones mounted in 61 cm diameter parabolic reflectors. The most successful procedure stationed three radio-equipped recording teams about 1000 m apart with the middle team eliciting the response. Under ideal conditions (no wind, low background noise, flat terrain and no intervening woody vegetation) analyzable recordings could be made of responses from as far as 1500 m.

Analysis of sound types was with a Kay Electric Company 6061-B Sound Analyzer using the narrow band filter.

Analysis

To analyze and understand coyote sounds, it was necessary to produce a sound spectrogram of the entire response, particularly when several animals were involved. This resulted in a sonagraphic display, several to many meters long, of many individual sonagrams spliced together. When two or more animals were simultaneously calling it was sometimes impossible to determine, either from the sonagram or the tape, when one animal stopped and another started. For this reason analysis and documentation of all segments of all spectrographically displayed sounds was not possible. This was particularly true when the vocalizations were recorded from extreme distances or under adverse conditions. Nevertheless, from the sonagrams and the tapes certain sounds were distinctive, occurred repeatedly and could be recognized.

Figs. 1A-1B, and 2A illustrate some of the problems of analysis. Fig. 1B shows a sonagram of a howl in which the lowest harmonic or fundamental was also the dominant frequency (Broughton, 1963; Waring, 1970). This condition, in which the fundamental (first harmonic) was the dominant frequency, was generally the situation for most sounds. In Fig. 1A, three harmonics were also present, but the 2nd harmonic rather than the fundamental was the dominant frequency (shown by the width of line and confirmed by sectioning). Fig. 2A shows an example in which the dominant frequency shifted between the 2nd and 3rd harmonic and the fundamental was never of an amplitude warranting consideration as the dominant frequency. Fig. 1E illustrates another condition. Here the animal began the howl with a modified bark, maintained a constant pitch and amplitude for 1.4 sec. At 1.4 sec a vibrato began in which the pitch varied, additional harmonic overtones (resultants or subharmonics) appeared and the dominant frequency shifted from the fundamental to what was, at the beginning of the howl, the 2nd harmonic. (See Watkins, 1967 for a possible explanation of this acoustic change in terms of changes in pulse-repetition rates). To achieve consistent analysis from one sonagram to another, the recorded Hz (cps) of the sound at particular points was based on the Hz of the fundamental and resulting harmonic spacing. Sonagrams of piano notes from low C to C above high C were prepared because the harmonic spacing of piano notes with fundamentals of known Hz could be matched with the harmonic spacing of coyote sounds of unknown Hz. This technique produced quantifiable readings that were consistent from one sonagram to another; avoided the problem of harmonic dominancy and those instances in which the dominant frequency shifted from one harmonic component to another during the duration of the call. Because sounds did not always maintain a constant pitch for the duration of the call, Hz determinations (i.e., matching piano note sonagrams with coyote sonagrams) for sounds of more than .4 sec duration were made at the beginning, about the middle and at the end of the call. The lowest Hz were at the beginning or the end, but the highest Hz were not always at the precise middle of the call. For this reason the middle reading point was arbitrarily shifted to include the highest Hz attained by the vocalization. Duration of the sounds was determined to the nearest .1 sec with a scale overlay.

Description of Sound Types

Coyote vocalization can be divided into two broad categories: (1) long sounds (Tembrock, 1963), continuous in form (Theberge and Falls, 1967), with a duration generally in excess of 1 sec and (2) short sounds (Tembrock, 1963) generally less than 1 sec duration and usually uttered in a repetitive fashion.

Continuous vocalizations

The flat howl (Fig. 1A-1B-1C-1D) was the commonest of the long sounds. The flat howls depicted in Fig. 1A-1B show smooth beginnings with a sharp rise in frequency or pitch in the first .1 sec, followed by a more gradual pitch rise, leveling off prior to, or around, the middle of the howl. A howl of this type then maintained, with some exceptions, a fairly constant pitch and intensity until the last .1 - .2 sec when the Hz and the amplitude varied slightly or decreased (Fig. 1A-1B-1C-1D). A coyote flat howl was not always flat, but might be arched with the highest frequencies somewhere near the middle as in Fig. 1C. Fig. 1C-1D show flat howls with irregular beginnings preceded by short sounds. Fig. 1A shows a flat howl with a smooth beginning preceded by a bark. Of 52 elicited flat howls in which the beginning was apparent, 80 per cent began with a bark (Fig. 1A) or a modified bark (Fig. 1D). These barks, particularly the modified barks often fused into a howl (Fig. 1D) as described by Tembrock (1968) and may be the same as the "herald barks" mentioned by Mengel (1971). Single responding animals commonly preceded the flat howl with one or more barks, particularly if they were close by. Spontaneous flat howls from single animals generally omitted the opening bark(s), but frequently incorporated a single modified bark into the beginning of the howl. (Fig. 1A shows one of three spontaneous howls from an animal probably aware of my presence as indicated by the opening bark). Opening evoked vocalizations of distant packs were nearly always flat howls of the type shown in Fig. 1B with no preceding short sounds. Opening evoked responses from nearby packs, however, generally were preceded by barks.

Table 1 provides data on Hz and duration for available spontaneous and elicited flat howls. There were no significant differences in Hz or duration between elicited and spontaneous flat howls for the samples available. This vocalization type was comparable to the C. lupus howls described by Theberge and Falls (1967).

The warble howl (Fig. 2A-2B) was a variable howl characterized by rhythmic changes of pitch and amplitude occurring at the rate of five or more times per sec. The degree of pitch change was variable, but ranged upward from 60 Hz. In some instances of pronounced pitch change (latter part of Fig. 2A) most of the sound energy was directed into the fundamental with a de-emphasis of upper harmonic amplitude to produce a wah-wah-wah sound. The warble was sometimes completely interrupted at the troughs to produce a smooth shift from the warble to a yip-yip-yip pattern. Warbles were also transitional vocalizations from the bark to the flat howl (Fig. 1D) and the reverse sequence. The warble was a major component of nine per cent of elicited responses and a major part of 10 per cent of available spontaneous vocalizations. It was present in an additional 40 per cent of the spontaneous vocalizations. Fundamental frequencies of warble howls were in the same Hz range as other long sounds shown in Table 1.

Sounds intermediate in pattern between the warble and the flat howl, but in same Hz range, were sometimes produced by coyotes. These were wavering sounds and the middle part of

Fig. 2A gives an example. The pitch change, as in the warble was variable, but generally less than 60 Hz and with less than five pitch changes per sec. This sound was a major part of only 2 per cent of the analyzed elicited vocalizations and an identifiable, but minor part of 16 per cent of the additional analyzed responses. It was not a major part of any analyzed spontaneous sound and as an identifiable part occurred only 10 per cent of the time. These data suggest that the waver sound was a recognizably distinctive sound of coyotes, but was not a major sound type and should be regarded as a variant of the warble or the flat howl.

The scream (Fig. 2C and first .9 sec of Fig. 2D) was a high pitched penetrating sound in the 1000-2200 Hz range characterized by a single intense dominant frequency and a general absence of additional harmonics. When harmonic overtones were present they were of very low amplitude (Fig. 2C). The configuration of screams was flat with gradually decreasing pitch and amplitude from beginning to end. The duration varied from .5 sec to 1.8 sec. Screams were generally not preceded by short sounds. They were heard mostly in elicited choruses, and were not part of the repertoire used by single responding adult animals. Because screams were common vocalizations of known juvenile coyotes in Marshall Co., Okla. this sound may simply represent attempts by juveniles to produce flat howls. Screams from single juveniles were sound types evoked from animals within about 125 m of our presence. This suggests these sounds might be warning or defense sounds. (Tembrock, 1968).

The gargle (Fig. 2D) was characterized by more than 20 pitch changes per sec with a magnitude of less than 50 Hz change. Because gargles lacked strong upper harmonics, they too may be juvenile variants of the flat howl and not a major component of coyote vocalization.

Combination howls (Fig. 1E and to a lesser degree, Fig. 2A) were continuous sounds in which two or more different long sounds were combined without any particular type dominating the vocalization. Barks were often incorporated into combination howls at the beginning and end as in other long sounds. Fig. 1E shows a combination howl involving a modified bark, a flat howl and a warble howl in one continuous sound. The kind and sequence of sound combinations, however, was extremely variable and future studies should be directed toward an analysis of the sequences used in this vocalization type. Combination howls most commonly occurred when more than one animal was calling (Figs. 2A-3A) particularly toward the middle and the end of both spontaneous and elicited choruses. Table 1 gives Hz and duration data of elicited combination howls and shows they did not differ significantly from other long sounds in Hz or duration. The few available spontaneous combination howls were in the same Hz ranges as other long sounds.

The laugh (Fig. 3C) was a particularly distinctive howl heard and recorded only from spontaneous choruses. Fig. 3C shows that a laugh (so termed because of its sound) consisted of a broken irregular howl ending in a modified warble. The configuration, duration and Hz of the laugh shown in Fig. 3C was typical.

Sometimes long sounds did not fit any of the preceding categories and did not occur in recognizably consistent patterns. These uncategorized vocalizations were designated <u>irregular howls</u> and examples are shown in Figs. 2E-3B. Table 1 shows that elicited irregular howls did not significantly differ in Hz or duration from flat or combination howls. Fifteen per cent of the analyzed elicited vocalizations were of an irregular nature.

<u>Discontinuous or Short Vocalizations</u>

Short sounds exhibited a spectrum of types shading from one to another and in the same Hz range as the long sounds in Table 1. The <u>bark</u> (Fig. 1A-1C) and first syllable of Fig. 3E was an explosive sound appearing sonagraphically as a smudge of about .1 sec duration. If clearly defined harmonics were present they were broad, intense and relatively flat as in Figs. 1A-3E. Scott (1968) provided a sonagram of dog barks showing the same general configuration as coyote barks, but of longer duration. Coyotes frequently produced modified bark sounds (Fig. 1D) with one-several arched harmonics and little or no smudging between the harmonics. These sounds were generally more musical and higher pitched than the explosive barks (in part because the upper harmonics were of greater amplitude than in explosive sounding barks). Both barks and modified barks were often connected to form a warble (Fig. 2B).

Several simultaneously responding coyotes produced variable, high pitched sounds. These intermediate duration sounds (Fig. 3D) had most, if not all the sound energy directed into a single dominant frequency, usually in the 1000-2500 Hz range. Yips (Pers. Comm., letter dated 10 Mar 1975 from Philip N. Lehner, Dept. of Zoology and Entomology, Colorado State Univ., Ft. Collins, Colo.) appeared sonagraphically as irregular arched sound forms with a duration of .1 sec to almost .4 sec. Short-howls (Fig. 3D) were sonagraphically displayed as relatively flat sound forms somewhat longer in duration than the yip and in a lower Hz range. Both these sound types were uttered repetitiously during a chorus.

The yipe (Fig. 3E) was recorded only from elicited chorus responses. It was a distinctive sound in which two harmonics were present in a double syllable sound with the upper harmonic of the greatest amplitude.

Other sounds have been noted and recorded from both South Texas and other coyote populations, but not often enough to provide adequate descriptions. These were apparently short-distance sounds of low amplitude. Phonetically, these sounds were labeled the growl, the snarl, the squeak and the whine (the latter term from Philip N. Lehner, Pers. Comm.).

Choruses

Elicited responses from more than two coyotes at a time followed a fairly predictable pattern. The opening response was usually a flat howl from a single animal. If the animals were nearby the opening flat howl was usually preceded by a bark. Prior to or after conclusion of the opening howl, another flat howl from a second animal was given. This pattern was ordinarily repeated for two-five howl sequences or for seven-10 sec with some silent spots between howls. The flat howls then shifted to warble, irregular (as in Fig. 3B) or combination howls all of less duration and amplitude than early in the chorus. The irregular and combination howls were joined with a series of yips and short-howls from other animals. Yips and short-howls of particular animals were uttered at intervals of .1 - .3 sec, but because several animals were calling silent spots were absent (Fig. 3D). This wild cacophony of sound typically continued for 15-30 sec and ended in two ways: (1) the chorus of yips and short-howls simply wound down and stopped or (2) prior to termination of the chorus one or more conbination howls ending in a short warble (an example is given in Fig. 3A) was given by a single animal. After the first of these terminal combination howls the yips and short-howls diminished in intensity and then ceased altogether. The last sound of the chorus was usually a combination howl from a single animal ending in a gruff bark. An entire elicited chorus was seldom longer than 60 sec in duration and averaged about 42 sec. Based on admittedly limited evidence, spontaneous choruses tended more to long sounds with less short sounds than elicited choruses.

Discussion

For a species as vocally variable as coyotes, I make no claim that the preceding data include all kinds of long-distance sounds made by these animals. On the basis of available spectrographic and acoustic data, two basic or primary sounds are produced by adults. These are the bark and the flat howl. The warble howl is a transitional sound between the bark and the flat howl. An additional sound form, the combination howl, incorporated two or more of these sounds to produce an additional important and recognizable sound. The simplest adult coyote sound is the bark and there appears to be a continuum of increasing phonetic complexity through the bark - modified bark - warble howl - flat howl - combination howl sounds. All these sounds are produced in both single and group circumstances. Of uncertain relationship to the above-listed adult sounds are the yip, short-howl, laugh and irregular howl, all of which are characteristically given in group situations. Screams and gargles are sounds characteristically produced by immature animals.

If howling is a means of communication (Theberge and Falls, 1967), and I have no doubt it is, then the other sounds also convey information. The behaviorial context in which the various coyote sounds were given was not known often enough to permit a reliable estimate of the informational message. Theberge and Falls (1967) discussed variation in amplitude and Hz of fundamental as a way in which specific information could be conveyed by the howl of *C. lupus*. Additionally, in coyotes, information may be coded in (1) type of call or variant thereof, (2) duration, (3) variation in Hz and amplitude of any of the harmonic components and (4) sequences and combinations of two or more different sound types.

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Table 1. Number, mean, standard error of mean and extremes for beginning, middle (highest) and end of indicated howl types. Mean, standard error of mean and extremes for duration of each howl type are also shown.

Locality	N	BEGINNING Hz	MIDDLE (Highest) Hz	ENDING Hz	DURATION
ELICITED FLAT HOWLS					
Welder	34	680 ±25 (475-1260)	946 ±53 (528-1500)	688 ±26 (366-1126)	2.0±.12 (1.0-3.0)
Webb-Duval	18	639 ±19 (495-792)	943 ±54 (660-1500)	697 ±23 (563-880)	2.4±.18 (1.4-4.2)
SPONTANEOUS FLAT HOWLS					
Welder	5	636 ±23 (563-704)	1062 ±92 (750-1320)	821 ±71 (630-1056)	1.6±.15 (1.1-2.1)
Duval	4	603 (563-660)	872 (630-1320)	730 (630-880)	2.6 (2.2-3.3)
ELICITED COMBINATION HOWLS					
Welder	12	718 ±46 (528-1056)	842 ±78 (528-1408)	711 ±44 (528-1056)	2.0±.12 (.9-3.6)
Webb-Duval	10	702 ±44 (563-1056)	997 ±63 (594-1408)	754 ±44 (594-1056)	2.0±.15 (1.3-3.2)
ELICITED IRREGULAR HOWLS					
Welder	14	622 ±21 (495-750)	649 ±24 (495-836)	672 ±45 (495-1088)	1.9±.12 (1.1-2.7)
Webb	2	656	935	711	3.0

Fig. 1. Sonagrams of coyote sounds. Frequency in 1000 Hz intervals shown by vertical scale and time by horizontal scale. (A) Bark, flat howl. (B) Flat howl. (C) Bark, bark, flat howl with modified bark incorporated in beginning of howl. (D) Modified bark changing to flat howl via warble. (E) Combination howl consisting of modified bark, flat howl and warble howl.

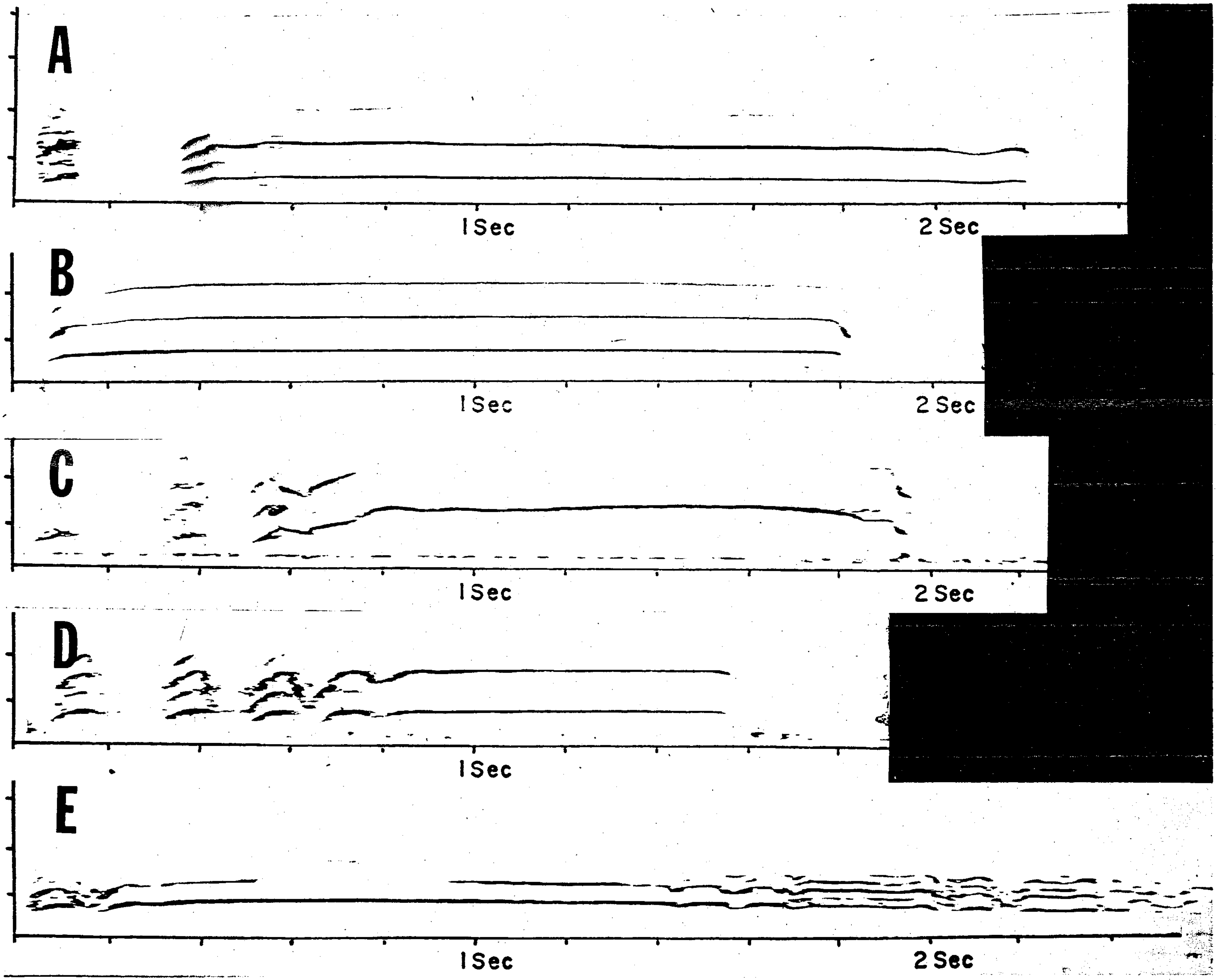
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Fig. 2. Sonagrams of coyote sounds. Scales as in Fig. 1. (A) A type of warble howl. The last .6 sec of sonagram shows another variant of warble howl. (B) First 1.4 sec shows a bark leading into a warble howl. Latter .6 sec shows beginning of scream. (C) Continuation of sonagram B to show rest of scream. (D) scream and gargle. (E) Irregular howl (darkest lines) accompanied by irregular howls of at least 2 additional animals.

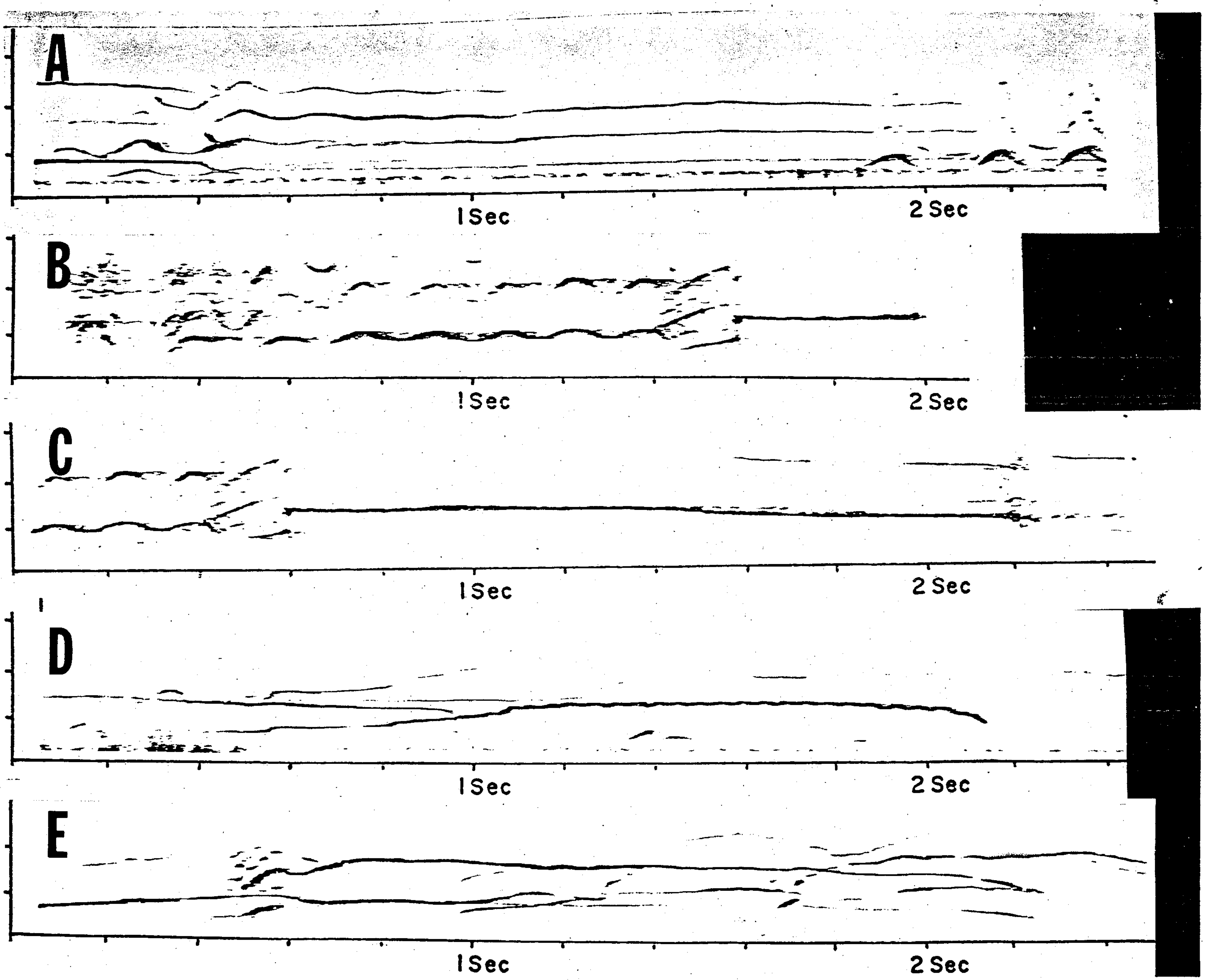
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Fig. 3. Sonagrams of coyote sounds. Scales as in Fig. 1. (A) Combination howl consisting of warble, flat and modified warble (accompanied by one additional coyote). (B) Irregular howl in chorus. (C) Laugh (with irregular howl in background). (D) Yip (y) and short-howls (h) in chorus. (E) Bark followed by yipes and ending in yip.