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Howling as a Means of Communication in Timber Wolves

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SYNOPSIS. The communicatory function of howling was studied in three adult male timber wolves *(Canis lupus)*. Approximately 700 howls were subjected to spectrographic and auditory analysis. The fundamental frequency of howls was divided into beginning, mid-section, and ending, and each section was studied separately. Harmonic features were also examined. Much variation was found within the howls of each individual. However, unique features were found in all howls of two wolves, of potential value in individual recognition.

The variation in characteristics of the fundamental within howls of individuals was tested to see if it related to features of the animal's behavior or environment. Eleven significant relationships were found. The characteristics involved were considered potentially functional in conveying information of a behavioral or environmental nature.

Auditory discrimination was studied by stimulus-response experimentation involving simulated wolf howls by humans. By either howling in response or remaining silent, one wolf demonstrated an ability to detect the slight difference between live howls and recorded, played-back howls. This ability enhances the possibility that individual recognition and conveyance of information may take place by means of differences in howls.

Analysis of the circumstances in which spontaneous howling (no known auditory stimulation) occurred demonstrated that isolation resulted in increased howling.

A form of long-distance communication is important to a social unit whose members are often separated. This study suggests that howling identifies the species, functions in the location of specific animals, provides specific information about the howling animal, and is, therefore, of great value in coordinating the social activities of wolves.

This paper reports on a study of howling as a means of communication in timber wolves *(Canis lupus)*. Howling is but one form of sound emitted by wolves. Others are the bark, whine, yelp, whimper, and growl (Tembrock, 1963; Colby, 1965; Huxley and Koch, 1938). Howling is common in the Family Canidae, especially in the genus *Canis* (Tembrock, 1963). Although a knowledge of communication is essential to understanding social behavior, little is known about the acoustic behavior of animals that howl, or the sound form itself. This study attempted to answer five questions: (1) What are the properties of wolf howls and how much variation exists in them? (2) Does variation in wolf howls relate to behavior or any circumstances surrounding howling and thus represent units of potential information? (3) What ability does a wolf have to distinguish variations in sound? (4) What circumstances surround spontaneous howling (howling which was not elicited by known auditory stimulation)? (5) What is the ecological significance of howling?

The study was carried out at the Wildlife Research Station of the Ontario Department of Lands and Forests in Algonquin Provincial Park, Ontario, during the summers of 1964 and 1965.

Three wolves were used in the study. All were male members of the subspecies *lycaon* (Young and Goldman, 1944), born wild, but captured when approximately one month of age. They had spent their lives, with the exception of Wolf B, in the pens at the Wildlife Research Station. Wolf B was allowed partial freedom up to the time he was two years old. The ages of the wolves in the spring of 1964 were: Wolf A

—two years, Wolf B—four years, Wolf C—three years.

In the summer of 1964, a pen was erected 3.5 miles from the Wildlife Research Station. This afforded both physical and auditory isolation from other captive wolves for experimentation. Wolf A was housed at this location for three months. In the summer of 1965 the pen was re-constructed one-quarter mile away from the group pens at the Wildlife Research Station, affording visual isolation but not always auditory isolation. All three wolves were housed individually for short periods of time (2-3 weeks) at this location.

In 1964, tests were conducted and recordings made from a cabin approximately 70 feet from the pen. A window afforded a view of the pen, but due to its placement did not allow the wolf to see the observer. In 1965, experiments were conducted from a tent 50 feet from the pen.

In both summers as many howls as possible were recorded. Recordings were made with a Uher 4000 Report-S tape recorder and microphone at 7½ inches per sec. Sound analysis was made with an audiospectrograph (Missile Data-Reduction Spectrograph, Kay Electric Co., Pine Brook, N. J.). Analysis was also carried out by ear with the aid of a pitch pipe.

DESCRIPTIVE ANALYSIS OF WOLF HOWLS

An effort was made to describe howls and ascertain the extent of individual variation by examining features of the howls themselves. Howls elicited by auditory stimulation and those given spontaneously were grouped for analysis. Features of the sound fundamental will be treated separately from harmonics.

Sound fundamental

By definition, the fundamental is the lowest frequency in the sound produced by a vibrating string. In the case of wolf howls it was also the loudest frequency, and the analysis of the form of howls was based upon it.

Howls were divided for analysis into three parts: beginning (the first 0.5 sec), ending (the last 0.5 sec) and mid-section (the howl between the beginning and ending).

Beginning. Three types of beginnings were apparent: one in which the howl began on a comparatively low note and broke upward abruptly to a high note, one which began on a high note and decreased gradually in pitch or remained at a constant pitch, and one which rose smoothly in pitch (Fig. 1). Each wolf showed a marked individual preference for type of beginning of howls (Table 1, i). Wolves B and C both showed a preference for beginnings that broke upward in pitch. In Wolf B, this type

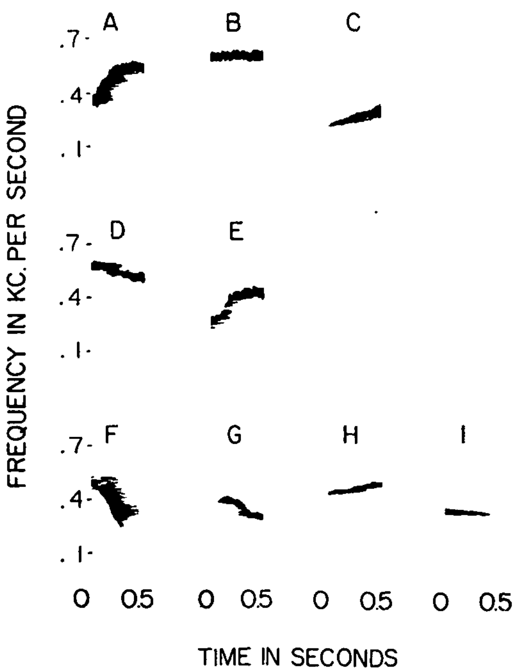

FIG. 1. Sonograms of sections of the fundamental frequency of wolf howls.
Beginning of howls (first 0.5 sec)
A, Break upward. B, Begins high. C, Smooth rise.
Part of mid-section of howls
D, Sudden drop in pitch. E, Rise in pitch.[1]
Ending of howls (last 0.5 sec)
F, Slur. G, Drop (not as abrupt as slur).
H, Rise. I, Steady.
[1] Rise in pitch incorporating the highest note of the howl and rise in pitch not reaching the highest note both appear similar on a sonogram, differing only in their level of pitch with respect to the rest of the howl.

TABLE 1. *Occurrence of pitch characteristics in howls of three wolves. (Percent of each wolf's howls; sample size in parentheses.)*

Characteristics of howls	Wolves A	B	C
i Beginning			
Break upward	10.4	99.5	83.4
Begins high	1.5	0.5	16.6
Smooth rise	88.1	0	0
	(393)	(184)	(120)
ii Mid-section—sudden drop			
No drop	76.9	32.6	26.8
One drop	21.9	27.1	37.5
Two drops	1.0	40.3	35.7
	(381)	(175)	(117)
iii Mid-section—rise incorporating highest note of howl			
No rise	13.0	90.1	100.0
Rise	87.0	9.9	0
	(381)	(175)	(117)
iv Mid-section—rise not reaching highest note of howl			
No rise	91.5	97.2	66.9
One rise	8.5	2.2	26.8
Two rises	0	0	6.3
	(381)	(175)	(117)
v Ending			
Slur	19.3	91.6	47.5
Drop	7.7	0	10.7
Rise	.01	0.5	7.4
Steady	72.6	7.9	34.4
	(391)	(187)	(120)

of beginning occurred in all but one howl. Of the howls of Wolf A, 88.1% were distinctive from all the howls of the other wolves, since he was the only wolf producing beginnings that rose smoothly in pitch.

Mid-section. Three characteristics involving change of pitch are obvious to the human ear in the mid-section of howls. They are: a sudden drop in pitch (at least three semi-tones in 0.25 sec or less), a rise in pitch incorporating the highest note of the howl (the highest note might be found in the beginning or the mid-section of a howl—a difference very distinct to the ear), and a rise in pitch which does not reach the highest note of the howl (Fig. 1). This last feature gives a measure of the amount of "warble" in a howl.

Most of the howls of Wolf A did not have a sudden drop in pitch in the mid-section (Table 1, ii). By contrast, Wolves B and C each gave about equal numbers of howls with no drop in pitch, one drop, and two drops.

The occurrence of a rise in pitch incorporating the highest note of the howl differed markedly among the wolves (Table 1, iii). Once again Wolf A differed from the others since his howls usually exhibited this feature while theirs did not.

Howls of Wolves A and B only occasionally showed a rise in pitch not reaching the highest note of the howl while those of Wolf C often contained one rise and occasionally two (Table 1, iv). Two rises were distinctive for Wolf C when they occurred (6.3%).

Ending. Four types of endings were apparent: one which slurred rapidly downward in pitch so that the final note could not be ascertained by ear, one which dropped less abruptly in pitch enabling one to ascertain the final note, one which rose in pitch, and one which remained steady or continued the rate of decline of pitch displayed in the mid-section of the howl immediately preceding (Fig. 1). Table 1, v, shows that Wolf A preferred a steady ending and Wolf B preferred a slurred ending, while Wolf C showed some preference for both these types.

Highest note of howls. The average highest notes reached by the fundamental of howls were: A for Wolf A (range of 14 semi-tones), C# high (*i.e.*, C# in the octave above middle C) for Wolf B (range of 5 semi-tones), and D# high for Wolf C (range of 8 semi-tones). Hence the pitch of howls was more variable for Wolf A than the other two wolves. The means for the three wolves were significantly different.

Lowest note of howls. Data on lowest notes existed for Wolves A and C only. Wolf B slurred most of his endings making determination difficult since the lowest note usually came at the end of a howl. Again Wolf A had the lowest mean (middle C) and the widest range (19 semi-tones). The average for Wolf C was F# (range of 9 semi-tones). There was a significant difference between the means for the two wolves.

Length of howls. Mean total lengths of howls varied significantly among the wolves.

Averages for Wolves A, B, and C were 3.5 seconds (range of 8 seconds), 4.7 (range of 6 seconds), and 6.4 (range of 11 seconds), respectively.

Sound harmonics

Vibrations of the vocal cords produce a fundamental and numerous harmonically related overtones (harmonics) (Fletcher, 1953). Twenty-five randomly picked howls of each wolf were analyzed by means of the audio-spectrograph to determine harmonic content. The presence or absence, and the relative strength, of various harmonics helps create the quality of the sound. Relative intensity was assessed by the relative width and darkness of lines on sonograms. The first harmonic is the first overtone above the fundamental and is an integral multiple of the fundamental. Likewise, the second harmonic is the second overtone above the fundamental.

First harmonic. The sample of 75 howls contained 56 howls whose fundamental crossed a pitch level of G# (all howls of Wolves B and C and six howls of Wolf A, the latter's howls in the sample usually being lower than G#). Forty-four of these 56 howls (79%) showed a decrease in intensity of the first harmonic at low pitches. This occurred in two of the six howls of Wolf A abruptly as the fundamental crossed G# (Figure 2, A) (in the four other howls of Wolf A that crossed G#, two showed the opposite and two showed no change). The other two wolves conformed to a greater degree. The decrease in intensity occurred in 17 of the 25 howls of Wolf B abruptly as the fundamental crossed G# (Figure 2, B), and in all the howls of Wolf C abruptly as the fundamental crossed F# (Figure 2, C). (In the remaining 8 howls of Wolf B there was no change in intensity.)

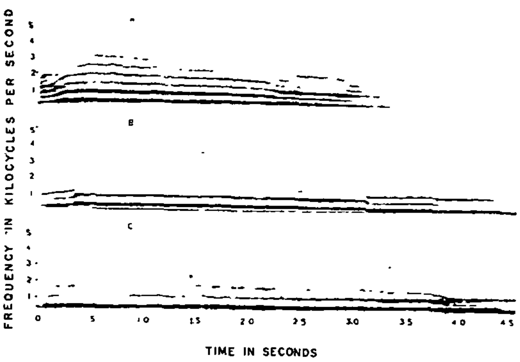

FIG. 2. Sonograms of the howls of wolves. The bottom wide line in each graph is the fundamental frequency. The first line above the fundamental is the first harmonic, etc.

A, typical howl of Wolf A.
B, Typical howl of Wolf B.
C, Typical howl of Wolf C.

Wolf C's first harmonic could be distinguished in all his howls from those of the other two wolves by a sudden increase in intensity when the pitch of the fundamental was between B and F# (Figure 2, C). and the aforementioned decrease at F#. Also, a decrease in intensity from D high upward was unique, not being shown by Wolf B. Howls of Wolf A did not reach this pitch.

Second harmonic. Of the 56 howls whose fundamental crossed G#, 44 (79%) showed an increase in intensity of the second harmonic at low pitches. This occurred in all 6 howls of Wolf A as the fundamental crossed G# to F# (Figure 2, A), in 13 of the 25 howls of Wolf B abruptly as the fundamental crossed G# (Figure 2, B), and in all the howls of Wolf C abruptly as the fundamental crossed F# (Figure 2, C). (In the remaining 12 howls of Wolf B, the second harmonic was uniformly weak throughout in seven, one petered out below G#, and four could not be determined.)

Higher harmonics. All of Wolf A's howls were much richer in harmonics above the second than those of the other two wolves, having a twelfth harmonic in one case. At most, Wolves B and C produced only weak third, fourth, and fifth harmonics.

DISCUSSION

From the results presented on the analysis of both the fundamental and harmonics, a howl may be described as a continuous sound from about half a second to 11 sec in length. It consists of a fundamental frequency which may lie between 150 and 780 cycles per sec, and up to 12 harmonically related overtones. Most of the time, the pitch remains constant or varies smoothly, and may change direction as many as four or five times. Total intensity does not vary greatly throughout.

This description encompasses the large amount of variation that existed in the howls of the wolves studied, and is consistent with the howls of wild wolves which the authors have heard. However, the sample studied was too small to consider this an adequate definition of wolf howls in general. The similarities in the pattern of intensities of harmonics in a large percentage of the howls studied (decrease in the intensity of the first harmonic at low pitches and increase in the intensity of the second harmonic at low pitches) may represent features that create quality in wolf howls in general, although this again needs confirmation with more animals.

The variation observed in almost all characteristics of the fundamental within the howls of each wolf provides a potential for coding information as far as the sound itself is concerned.

A high degree of "individuality" in the howls of each animal was due to individual preferences for type of beginning, type of ending, pitch changes in the mid-section of howls, and significantly different average highest notes, lowest notes, and lengths. Also, diagnostic features were present in the fundamental of many of the howls of two wolves, and in the harmonics of all the howls of two wolves. Thus, howls of different individuals were at least potentially recognizable by other wolves.

POTENTIAL INFORMATION IN WOLF HOWLS

If the variation in the fundamental within howls of an individual shown in the previous section is related to features of the animal's behavior or environment, it is potentially capable of conveying specific information to other animals.

A study was made to determine whether any of the characteristics previously discussed were associated with behavior (whether the wolf was lying, walking slowly, or pacing), or with the circumstances surrounding howling (whether or not prior to the howl an auditory stimulus was played to the wolf). Analysis for each characteristic was carried out by means of chi-square tests on contingency tables.

In the tests relating behavior with characteristics of howls, three relationships involving two characteristics (sudden drops in pitch in the mid-section of howls, and rise in pitch incorporating the highest note of the howl) were found (Table 2). Sudden drops in pitch in the mid-section of howls did not show the same relationship with behavior for both Wolf B and Wolf C. With Wolf B, howls lacking drops in pitch were associated more commonly than expected with pacing, whereas the reverse was true with Wolf C.

In tests relating whether howling was spontaneous (no known auditory stimulation) or stimulated with characteristics of howls, eight relationships involving seven characteristics were found (Table 3). Only one of these, highest note, occurred in the howls of both wolves which were analyzed. In both cases, the highest notes tended to be higher when howling was spontaneous rather than stimulated.

Communication can take place on two levels: universal and individual. Communication that is universal (occurring within the species in general) requires a symbolism that is the same throughout the species. The only characteristic found that might qualify was highest note, which showed the same relationship to whether howling was

TABLE 2. *Relationship between characteristics of howls and behavior* for Wolves A, B, and C.*

Characteristics of howls	Wolf A	Wolf B	Wolf C
Types of beginning	NR†	No test	NR
Types of ending	NR	NR	NR
Mid-section			
Sudden drop	No test	R‡	R
Rise incorporating highest note	NR	R	No test
Rise not reaching highest note	No test	No test	NR
Highest note	NR	NR	NR
Lowest note	NR	No test	NR
Length	NR	NR	NR

* Wolf lying, walking slowly, or pacing
† NR = no relationship
‡ R = relationship

TABLE 3. *Relationship between characteristics of howls and whether howling was spontaneous or stimulated for Wolves A, B, and C.*

Characteristics of howls	Wolf A	Wolf B
Types of beginning	R*	No test
Types of ending	R	NR†
Mid-section		
Sudden drop	NR	R
Rise incorporating highest note	R	NR
Rise not reaching highest note	NR	No test
Highest note	R	R
Lowest note	R	No test
Length	R	NR

* R = relationship
† NR = no relationship

spontaneous or stimulated in both wolves tested. A sample size of two wolves is obviously too small upon which to base a firm conclusion. Communication on the individual level may occur between animals that have learned to recognize individual traits in animals with which they are associated. In this regard, all relationships found in this section (Tables 2 and 3) represent cases where conveyance of information to other animals familiar with the individuals in question could take place.

AUDITORY DISCRIMINATION

To establish that a communicatory system is in operation, something must be learned about the ability of the receiver. In 1964, stimulus-response experimentation was carried out involving simulated wolf howls by humans. The experimental wolf responded by howling when exposed to the live (non-recorded) simulated wolf howl of Mrs. Theberge in 39 out of 43 tests conducted over a period of three weeks. However, when the same sound was recorded and played back to the wolf through either a 12-inch speaker in a box enclosure or the monitor speaker of the Uher tape recorder, response occurred in only two of 25 tests. In all cases, the source of the sound was out of sight of the wolf. By means of spectrographic examination, three acoustic properties were found in played-back recorded howls that differed from live howls: slight distortion of the fundamental, reversal of the relative strength of the first two harmonics, and a slightly lower total volume. One or all of these differences provided the basis for discrimination of live from recorded human howls.

The possibility that individual recognition and conveyance of specific information may take place through howls is strengthened, since it has been demonstrated that the animal can detect subtleties in sound.

CIRCUMSTANCES IN WHICH SPONTANEOUS HOWLING OCCURRED

By definition, spontaneous howling was howling given with no known auditory stimulation. A large percentage of the howls recorded during this study fell under this definition. The data collected in 1964 were examined to determine if any environmental factor or factors were influencing this howling.

The total amount of time the experimental wolf was isolated from his pen mates could be divided into three categories as follows: (1) Hours when either Mr. or Mrs. Theberge was present in the cabin near the wolf pen. (2) Hours when the wolf was left entirely alone, or presumed to be alone. (3) Hours following arrival back in the area of the pen after an absence. This category was arbitrarily separated from Category 1 by being defined as including 15 hr immediately following a return to the pen area after an absence of at least 5 hr. These 15-hr periods are, therefore, not included in Category 1.

Rate per hour of spontaneous howling "occasions" was calculated for each category. "Occasion" is defined as a series of howls given in rapid succession with no more than 15 sec between individual howls. This was the normal pattern of howling of Wolf A, the animal being discussed. The number of hours in Category 1 was an estimate. Category 2 was restricted to hours when an observer was still within hearing distance and could note when howling occurred.

Table 4 shows that the rate of howling varied enormously depending on environmental circumstances. The highest rate occurred while the wolf was alone, a medium rate while someone was in the area of the

TABLE 4. *Amount of spontaneous howling as it relates to environmental circumstances.*

Environmental circumstances category	No. of hours	No. of howling occasions	Howling occasions per hour
1*	1200+	11	0.009
2†	20	68	3.4
3‡	400	78	0.19

* Someone present in the pen area
† Wolf left alone
‡ Someone present in the pen area after an absence

pen but had been absent immediately before, and the lowest rate when someone had been present for at least 15 hr. The medium rate in Category 3 may have been the result of a carry-over from previous isolation (Category 2).

Isolation has been reported to lead to vocalization in puppies. Scott and Bronson (1964) suggest that "the emotional response to isolation may function as a general motivational basis for maintaining social contact." It is a common observation that adult dogs will vocalize when confined alone. The evidence presented in this study suggests that isolation also results in increased vocalization in wolves.

ECOLOGICAL SIGNIFICANCE OF HOWLING

Wolves are highly developed socially (Schenkel, 1947; Etkin, 1964), forming groups which occupy fairly distinct territories (Mech, 1962). In order to function as a group, communication among individuals is necessary. Wolves communicate at close range by facial expression, tail position, body posture, scent, touch (Schenkel, 1947), and vocalization. Obvious, close-range, vocal communication observed with captive wolves at the Wildlife Research Station included whining, snarling, and a low bark. Also observed by many writers is the so-called social or group howling, a common phenomenon of the captive wolves at the Wildlife Research Station, and heard many times during field studies in which Theberge took part (Pimlott, 1960).

The habits of wolves require members of a social unit to be visually separated at times so that only olfactory and auditory means of communication are possible. Single wolves were often heard howling in the field studies mentioned above. It seems reasonable that a social species with such habits and having little to fear from natural enemies should have evolved a form of vocal communication effective over long distances.

Evidence was presented on the propensity of a wolf to howl when separated from members of its social unit (in this case, humans). Such howling may impart information. The common features of both the fundamental and harmonics may identify the source of the sound as a wolf. Information on the location of the wolf may be provided. Dogs are able to detect the location of a sound source with great accuracy (Katz, 1961). Murie (1944) cites examples in which howling brought other pack members to a single howling animal. We know of a number of occasions when wolves came to human simulated wolf howls or to recorded wolf howls during field studies in Algonquin Park.

By imparting information on location, pack members may stay in contact with one another. Vocal advertisement of territory, as is believed to exist in howler monkeys (Carpenter, 1934), may also take place, although this study has presented no evidence in this regard.

It has been demonstrated in this study that unique features exist in the howls of individual wolves. Harmonic characteristics were found that would distinguish individuals on the basis of any one howl. This fact means that wolf howls may provide a basis for individual recognition. The ability of a wolf to detect subtleties in sound indicates that reception of this information is possible. The significance of individual recognition from howls is obvious in both location of specific individuals and efficient advertisement of territory.

Characteristics of howls were found to be related to behavior of the howling wolf and circumstances surrounding howling. This fact, again coupled with the ability of a wolf to detect subtle differences in sound, suggests that specific information about the howling animal may be communicated, at least to other members of its social group.

If howling serves some or all the functions suggested above, it is of great value in coordinating the social activities of wolves.

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