# VOCAL REPERTOIRE OF THE CACTUS WREN

(*Campylorhynchus brunneicapillus*)

by

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ABSTRACT

A physical and behavioral analysis of the vocal repertoire of the Cactus Wren (Campylorhynchus brunneicapillus) was based on field tape recordings, observations of behavior, and sound spectrograms. Adults have nine categories of vocalizations: the song and eight call-notes (two warning, a fight, pair-bond maintenance, two location, a distress, and one of unknown significance). Fledglings and juveniles have eight vocalizations: a subsong, a rehearsed song, and six call-notes (two warning, a fight, two location, and begging call). Nestlings have five call-notes (three begging, a location, and a distress call).

There are at least 32 variations of the adult song and an undetermined number of variations in the adult warning calls. Variations of the song have distinct syllable patterns with characteristic syllable lengths and rate. By contrast each category of call-note has a constant syllable pattern, but shows variation in syllable length and rate.

It appears that the Cactus Wren has phase and time differences and not intensity differences in calls used to locate the position of the individual.

# INTRODUCTION

Earlier papers dealing with vocalization studies employed phonetic descriptions of sounds and not quantitative parameters such as frequency range, vocalization rate, and sound patterns. Recently improved electronic devices, such as portable tape recorders and sound spectrographs, have made possible field recording of good fidelity and the detailed analysis of sounds. These advancements have greatly increased the objectivity of vocalization studies within the past 10 to 15 years. It is now possible to see and measure details on sound spectrograms that the most highly trained human ear can not differentiate.

In this study the vocal repertoire of the Cactus Wren (Campylorhynchus brunneicapillus) is described by spectrographic analysis and correlated with field observations of behavior associated with the vocalizations. The repertoire includes vocalizations of the adult, juvenile, fledgling and nestling wrens.

This study of Cactus Wren vocalizations is intended to provide a basic description for future studies, in which the repertoire may be used to determine phylogenetic relationships on the specific, generic and family levels, as suggested by Marler (1956b).

## TERMINOLOGY

I have found it necessary to define the terminology used in this paper because the general literary terms for bird vocalizations do not fully apply to this study. I have quoted some definitions which apply to birds generally, and have noted how these definitions differ when applied to the Cactus Wren. All other terms I defined specifically for this study.

### Pattern

A pattern is the arrangement of the sound energy on the sonogram.

### Formant

A formant is a region along the frequency spectrum of the sonogram with a large concentration of sound energy. These dark areas form patterns which help differentiate variations in the vocalizations.

### Syllable

As seen on a sonogram a syllable is defined as vocal sound energy separated in time by stops in that energy of at least 0.03 second, but less than one second.

## Complex Syllable

As visualized in the sonogram a complex syllable contains sound energy with many variations in formant patterns (Figs. 1-4, see pages 41-45).

## Simple Syllable

A simple syllable on a sonogram shows few variations in formant patterns (Fig. 5).

## Utterance

An utterance is any series of syllables separated by one second or more.

## Noise

Noise is unmusical sound. It is seen on the sonogram as vertical spikes. All Cactus Wren vocalizations contain some noise except the nestling *peep*.

## Song

Thorpe (1961) defines the physical structure of song as ". . . a series of notes, generally of more than one type, uttered in succession and so related as to form a recognizable sequence or pattern in time." Since I can not differentiate notes in Cactus Wren vocalizations, "sound energy" is substituted for "a series of notes" in Thorpe's definition. Anderson and Anderson (1957) define the Cactus Wren song functionally as ". . . the vigorous vocal

expression that coincides with the establishment and maintenance of the Cactus Wren's territory."

## Subsong

The subsong is one of the stages in the development of the primary or adult song (Lanyon 1960). The characteristics of the Cactus Wren subsong are great variation of frequency range, formant pattern, and syllable length within an utterance, when compared to the adult song.

## Rehearsed Song

Lanyon (1960) states there is a transition from the subsong to the next distinctive phase, the rehearsed song. He describes this song as ". . . the addition [to the subsong] of distinguishable vocal patterns that are suggestive of the definitive primary song." He says specific call-notes are interspersed with the rehearsed song. I have not found these notes in the Cactus Wren rehearsed song. Call-notes may be given immediately before or after the rehearsed song, but I have not seen on the sonogram call-notes within this song.

## Call-Notes

I consider all Cactus Wren vocalizations other than the song, the subsong, and the rehearsed song to be call-notes. This includes calls used for warning, location,

fighting, pair-bond maintenance, parent-young interrelations, and calls given by nestlings and fledglings.

Physically call-notes generally contain less complex variations in sound energy than the song. (See simple and complex syllables described above.) Thorpe (1961) states that, "When call-notes are uttered in longer series, then it is without any clear organization of the sequence into bursts [utterances] of definite length, the series continuing without interruption as long as the circumstances and the state of the bird dictate."

## METHODS AND MATERIALS

I made tape recordings and studied the behavior of Cactus Wrens on two study plots between May and August 1967 and between June and August 1968. The first study area is 12 miles east of Tucson, Arizona, at the junction of Catalina Highway and Santa Ana Lane. The second plot is at the east end of Speedway Boulevard, 17 miles east of Tucson, Arizona. These study areas are in the Lower Sonoran Lifezone, and contain the following dominant plants: palo verde, mesquite, sahuaro, cholla, prickly pear, and creosotebush.

The Cactus Wrens were banded with U.S. Fish and Wildlife Service aluminum bands and plastic color bands. In 1967 I banded 13 wrens, nine adults and four nestlings. In 1968 I banded 15 more wrens, seven adults, three nestlings, and five fledglings. I made sound recordings of both banded and unbanded wrens.

In 1967 I mist-netted wrens to capture them for banding. This procedure caused them to fear my presence, and it made it difficult for me to later record their normal activity. During the winter of 1967-1968 in the predawn hours, I caught the wrens by placing one end of a cardboard tube at the nest entrance. I had already attached a

pillow case to the other end of the tube. I flushed the wren into the pillow case, banded it, and placed it back in the nest. The wrens usually remained in the nest until dawn. I did note the few wrens that escaped while being replaced in the nest abandoned the nest permanently.

I used a Uher 4000L portable tape recorder at 7 1/2 inches per second, an Altec M50 condenser microphone or an Altec 689 Bx dynamic microphone, and Scotch 203 recording tape. I carried the highly directional microphone in my hand or fixed it in place at the nest entrance.

Recordings were analyzed by a Kay Electric Company Sound Spectrograph, Model 661A, with narrow filter band and high shape settings. Sonograms (or graphs of sound) made at the tape recording speed of 7 1/2 inches per second have a vertical axis indicating a frequency range from 85 cycle/sec to 4,000 cycle/sec and a horizontal axis representing 0.0 to 2.4 seconds.

Since some of the vocalizations contained frequencies above 4,000 cycle/sec, it was necessary in some cases to analyze them at one-half or one-quarter the normal recording speed of 7 1/2 inches per second. This effectively doubles or quadruples the frequency range to 8,000 or 16,000 cycle/sec and cuts the time base to one-half or one-quarter (1.2 seconds or 0.6 second).

I measured the physical characteristics of the vocalizations on the sonograms with scaled transparent plastic and graph paper that allowed accuracy to the nearest 0.1 kilocycle and 0.01 second on sonograms having a frequency range from 85 to 4,000 cycle/sec.

The frequency range and amplitude of the sound energy on the sonogram is determined partially by settings on the sonograph machine and tape recorder. The record-reproduce setting on the sonograph and the volume control on the tape recorder determine the amount of sound energy put into the sonograph machine. The mark level setting of the sonograph machine determines the darkness of the sonogram by altering the amount of electrical energy fed to the stylus. Although altering these settings still gives the same relative dark and light areas on the sonogram, the higher frequency ranges may not show up with low settings. There is a needle indicator to show the amount of energy put into the machine for a particular sound, and I tried to keep the highest needle reading constant. However, if there is background noise of high amplitude in the recording, the needle will indicate higher amplitude than is actually in the vocal sound and the vocalization will show up very light on the sonogram.

No accurate measurement of amplitude can be made from regular sonograms for two reasons. (1) The range of

amplitude of the sonograph paper is only six decibels. (2) There are variables in field recording with the method I used. For example, the bird may turn its head for different vocalizations, the recorder is not always the same distance from the bird, or the amount of foliage between the bird and the recorder may vary. One might be able to attach a transmittor to the bird's body to receive accurate recordings of the vocalization amplitude.

Often background noise, airplanes, highway traffic, cattle, other birds, and wind, will show in the sonogram. If they are of low amplitude and low frequency they generally do not interfere with the analysis of the vocalication.

I used the high shape setting on the sonograph machine to emphasize the high frequencies that attenuate in air more rapidly than the low frequencies. This gives a more accurate picture of the vocalization recorded at close range. I do not know whether another bird at a distance will hear these higher frequencies, but it is possible.

## ADULT VOCALIZATIONS

The nine adult Cactus Wren vocalizations are: the song *char*, the warning calls *buzz* and *tek*, the fight call *scri*, the recognition or pair-bond maintenance call *growl*, the two location calls, *rack* and *chuck*, a distress call, and a call of unknown significance best described as a squeal.

### The Song

The song consists of a series of similar syllables and is the most variable of all Cactus Wren vocalizations that I have analyzed on sonograms. Syllables vary and may be described phonetically as *char*, *chur*, *chir*, *rar*, or *rack*. (See Figs. 1-4 for variations in syllable pattern.) The song is given mainly by the male perched on top of a cholla cactus (*Opuntia* sp.), a tree, or other conspicuous place. The wren during the song is perched almost vertically, does not display the wings or tail, has the bill open and above the horizontal, and has the throat distended. Selander (1964) says the *Heleodytes* group fan the tail during the song, but I have never seen them do this. Anderson and Anderson (1957) say the female does not regularly sing, but when she does, it is weaker and often higher pitched. I have never heard a known female sing.

Physical Description of the Song

The physical description is based on the analysis of 43 sonograms. A song is an utterance composed of a series of complex syllables. Each syllable may last from 0.06 second to 0.14 second. Five to nine syllables may be given per second. The length of the utterance, measured by a stop watch from 46 random recordings, is from 1.0 second to 4.2 seconds and the average utterance is 2.5 seconds. The complex syllable is repeated without change within an utterance, but may change for the next utterance. The lowest frequencies of the 43 songs analyzed range from 85 cycle/sec to 700 cycle/sec. The highest frequency in 41 songs is 2,500 cycle/sec and is about 4,000 cycle/sec in two songs. The song may be heard throughout the year, but is commonly heard during the breeding season from February to July.

In the slower vocalizations there is a tendency for the syllable to be longer as the number of syllables per second decreases (Table 1).

Table 1. Syllable relationships of the song.

| Syllables per second | Length of syllables in seconds |
|---|---|
| 5 | .16 |
| 6 | .13 |
| 7 | .11 |
| 8, 9, 10 | .07 |

Behavior Associated with the Song

I have recorded or observed the Cactus Wren giving the song in a number of situations. In 62 cases I have correlated the song with specific behavior, but many other times I heard the song and could not observe the behavior associated with it.

At least 25 times as I approached the territory, the song was given, and it was usually followed by the two warning calls buzz and tek, as I approached the nest or family group. The song was recorded once when a Curve-billed Thrasher approached within a few feet of a fledgling. Once I accidentally fledged a nestling and the parents gave several songs. Two times the male gave the song when I approached close to a fledgling. This was followed by the two warning calls buzz and tek. These songs are associated with alarming situations. Although they are distinctly different, they have some common physical features. The syllables contain much noise and the formants form a sharp oblique up-and-down pattern (Fig. 1B).

Once the male song called the female to the male, and they flew off to a nest they were building (Fig. 1A). The syllable contains one area with three vertical inverted "u" formants almost without noise, which is suggestive of some of the nestling peeps. The second part of the syllable

contains vertical spikes that are characteristic of Cactus Wren songs.

On seven occasions the song was associated with nest building. The male put material in the nest and uttered three identical songs (Fig. 4I). The syllable contains two inverted "u" noisy formants, one at a higher frequency than the other.

On seven occasions the song was given intermittently with the feeding of fledglings. Four of the five sonograms of this song show a similar pattern. The syllables contain a horizontal formant pattern with an abrupt narrow peak at the top (Fig. 4H).

Six times the song was associated with a microphone placed at the nest entrance to record nestling vocalizations. It was followed by the two warning calls, buzz and tek, after which the wren usually attacked the microphone. The syllable is distinctly heard as rark and contains one main noisy formant (Fig. 2D). Although the readable sound energy ranges to 4,000 cycle/sec, the main sound energy is to 2,500 cycle/sec.

Ten times I observed the song given in volleys (the calling back and forth of birds on adjacent territories). When one listens to a volley, the song definitely changes from the beginning of the volley to the end. One volley between the wrens of territories I and VI was analyzed in

detail. I was recording from territory I, and although the wren from territory VI can be heard on the tape, it was impossible to make sonograms of VI's songs. Wren I gave 15 utterances during the volley. Five utterances were recorded from Wren VI. It was possible that Wren VI gave more utterances that were not recorded.

The syllable structure changed three times during the two-minute volley, and the length of the utterance changed with it. The first utterances ranged from 3.4 seconds to 2.0 seconds. The syllable structure changed and the utterances ranged from 1.3 seconds to 2.0 seconds. When the syllable changed again the utterances ranged from 3.0 seconds to 4.0 seconds.

The syllable structure was the same for the first five utterances (Fig. 3E). The three formants show a left to right oblique pattern and are divided by fine vertical striations.

The sixth, seventh, and eighth, utterances (Fig. 3F) have the same syllable pattern. The syllable has a formant running obliquely up-and-down twice. The last part of the syllable contains much noise.

Utterances 9 through 15 have the same syllable pattern (Fig. 3G). The syllable varies more than in any other adult song, and appears similar to the subsong except

the syllable length is very constant. The numerous formants show a varying pattern of coarse vertical spikes.

Twice I recorded a song in response to a wren on another territory, but not associated with a volley (Fig. 2C). The syllable has a horizontal formant pattern, and is heard as rar. The frequency range is a little over 4,000 cycle/sec.

The syllable pattern of 34 of the 43 song utterances analyzed were different. I found that songs of identical syllable pattern have the same syllable length, rate, and frequency range. I believe the change in the syllable pattern and associated physical characters is correlated with the nature of the stimulus.

## Buzz

Both the male and female give the warning call buzz. During the call the long axis of the body is almost horizontal, the bill in line with the body, the bill open, no display of the wings or tail, and the throat distended. The call is composed of a series of simple syllables which look on the sonogram like vertical stripes containing many vertical spikes (Figs. 5 and 6).

### Physical Description of the Buzz

I interpreted 29 sonograms of the buzz. The syllable length varied from 0.05 to 0.16 second, and there

were 4-10 syllables given per second. The frequency ranged from 85 cycle/sec to around 8,000 cycle/sec. The syllable may show one, two, three or more formants, each at a higher frequency range. The length of the utterance, measured by a stop watch from 45 random buzz calls, varies from 0.2 second to 17.0 seconds. The buzz is a commonly heard vocalization. On one tape I have 10.1 consecutive minutes of buzz utterances. These warnings probably would have continued longer if I had not left the territory.

The syllables tend to become shorter the greater the number of syllables given per second (Table 2).

Table 2. Syllable relationships of the buzz.

| Number of syllables per second | Length of syllables in seconds |
|---|---|
| 4, 5 | 0.14 |
| 6 | 0.12 |
| 7 | 0.10 |
| 8 | 0.07 |
| 9 | 0.06 |
| 10 | 0.05 |

The syllable pattern of all the buzz utterances I analyzed was subject to little variation. The buzz calls of six wrens, each from a different territory, show the same variation in the syllable rate, syllable length, and

frequency range. I believe this variation is due to the nature of the stimulus.

Behavior Associated with the Buzz Call

I have observed the buzz given in the following situations: (1) I heard it 34 times when I was on the territory and approached the nest or family group. (2) I heard it 47 times when I was at a nest containing young. (3) It was provoked three times by a Roadrunner on the territory. (4) I heard it eight times in territorial disputes. (5) I heard it directed once at people in the highway. (6) Six times I heard it associated with a microphone placed at the nest entrance. (7) I heard it once when I put a snake in a cage under the nest.

Twelve times I observed other Cactus Wrens come to the site of buzzing and begin to buzz. Four times, during persistent buzzing of the parents, the usually vocal nestlings were silent while being fed. Five times the microphone was attacked and pecked until it fell to the ground. When I was standing near the nest or staying on the territory after persistent buzzing, the wrens would often perch in a tree and preen intermittently with buzzing. I observed two interspecific responses to the buzz. Black-tailed Gnatcatchers often fly to the vicinity of the wrens, perch, and give a chee call intermittent with the buzz. Several times

I heard Gila Woodpeckers give calls intermittent with the buzz.

Cactus Wrens are often very bold when buzzing. Several times when I have been at a nest containing young, an adult wren approached so close that I could have touched it. When I put a Gopher snake in a cage on the ground under a nest, the wren perched on the top of the cage, looked down at the snake, and buzzed. From observations of banded males and females, it is usually the male that approaches the threatening object closely and buzzes while the female is perched at a distance. The female usually buzzes or teks also.

## Tek

Anderson and Anderson (1957) say the tek call is one of mild danger, and is succeeded by the buzz as the threat increases. Although the tek and buzz may be given one after another, or one bird in the background may tek while another in the foreground may buzz, the tek is usually given first and may be given last as the potential danger decreases or the predator retreats. I have four sonograms where the tek blends into the buzz (Fig. 6, tek left and buzz right). Both the male and female give the tek call.

Physical Description of the Tek

The analysis is based on 18 sonograms. The tek has a structure similar to the buzz, that is, a series of simple syllables forming vertical stripes containing noise (Fig. 6). However, the tek syllable is generally much shorter than the buzz syllable and usually does not contain the multiple formant pattern of the buzz. The tek is a stereotyped vocalization compared to the song.

The tek syllables vary in length from 0.01 to 0.04 second, and the number per second varies from 5 to 18. The frequency range is from 85 cycle/sec to about 7,000 cycle/sec, although a few tek calls range only to about 4,000 cycle/sec. The length of the utterance, measured by a stop watch from 20 random recordings, varies from 1.1 to 7.0 seconds. There is less correlation between the number of syllables given per second and the duration of the syllable than in buzz calls (Table 3).

Table 3. Syllable relationships of the tek.

| Number of syllables per second | Length of syllable in seconds |
|---|---|
| 5 | .04 |
| 7-10 | .02 |
| 13-18 | .01 |

The syllable pattern of all the tek utterances I analyzed was subject to little variation. The tek calls of several different wrens show the same variation in the syllable rate, length, and frequency range. I believe this variation in the call is associated with the nature of the stimulus.

### Behavior Associated with the Tek

I have observed the tek in the following situations: (1) 14 times when I approached the territory, (2) three times when I handled nestlings, (3) once when a Roadrunner passed through the territory, (4) four times during territorial disputes.

## Scri

I have observed both the male and female giving the scri call during territorial disputes.

### Physical Description of the Scri

The analysis is based upon ten sonograms. The simple syllable is composed of definite vertical spikes about 0.01 second long and separated by stops in sound energy of about 0.01 or 0.02 second (Fig. 9B). Although the vocalization is stereotyped compared to the song, the formant pattern is obscure and may vary from one vertical spike to another. The syllable as a whole appears very

noisy. Anderson and Anderson (1957) describe it as sounding like a metal-strip rake dragged through loose gravel.

The syllable length is 0.25 to about 0.33 second. One, two, or three syllables may be uttered at a time. Syllables are given at the rate of about two per second when more than one is given. Since a varying number of syllables may be given, the utterance varies from 0.25 second to about 2.5 seconds. The frequency ranges from 85 cycle/sec to about 8,000 cycle/sec.

Behavior Associated with the Scri

The scri is usually associated with territorial disputes and may be given before and during a chase. Often it is given in foraging groups of juveniles (described with juvenile vocalizations, pages 29-30). Once I observed the male of territory III singing. The female flew to him; he called scri, chased her a few feet, and then gave the recognition display and growl call.

Growl

The growl is probably a recognition or pair-bond maintenance call. I have recorded the call at least 20 times on several different territories; but I could make sonograms from the calls of only one territory, because this vocalization is of such low intensity that the microphone does not pick up the sound well.

The call is not stereotyped. Eight sonograms show seven different patterns from the same two birds. The seven different sonograms show some common characteristics.

Physical Description of the Growl

Figs. 7 and 8 contain syllable patterns that are common to all growl calls analyzed. Most of the syllables have a horizontal pattern, range from about 2 to 3 kilocycles and are about 0.2 second in length. They vary mainly in formant pattern and time between syllables. (There is a lapse of about 0.2 second between part A and B of Fig. 8).

Behavior Associated with the Growl

The growl is associated with a display between the male and female. The male spreads his wings and tail; the tail is somewhat depressed. Although I have seen the display numerous times, I cannot precisely describe the female's display. Anderson and Anderson (1957) note the female displays in a manner similar to the male and then crouches. It is probable the female gives part of the vocalization seen on the sonograms, but I cannot confirm that. The whole display lasts about three seconds. I have recorded it three times in one and a half minutes, although the time between the growl calls is variable. I have often observed the male and female giving the display

and growl when in close proximity. I have occasionally seen one of the pair fly to the vicinity of the other and not give a growl or display.

## Rack

I heard this call given infrequently by adults. The description is based on two recordings and two sonograms (Fig. 9A).

### Physical Description of the Rack

Each syllable is given about once per second. The syllable has a duration of from 0.39 second to 0.45 second and a frequency range from 500 cycle/sec to 2,200 cycle/sec. The overall pattern of the rack looks very much like some of the syllables of the growl call.

### Behavior Associated with the Rack

Anderson and Anderson (1957) stated the call seems to be for the purpose of locating the mate or other wrens. The two times I have recorded the rack another bird flew to the vicinity of the calling wren. I have heard juveniles giving the call more frequently than the adults, but have never recorded it.

## Squeal

Anderson and Anderson (1957) reported that this call is seldom heard. When given, it is by the male near

his roosting nest before a breeding nest is begun or completed. I have never heard or recorded this vocalization.

### Chuck

The adults use a chuck location call when feeding fledglings. This is discussed below with the fledgling chuck call.

### Scream

Twice, while I was banding wrens at night, birds screamed as I held them in my hand. I am sure I was not hurting the bird and believe the call was the result of extreme fear. I have no recordings of this call.

## JUVENILE AND FLEDGLING VOCALIZATIONS

I discuss commonly heard juvenile and fledgling vocalizations here and do not attempt to include all variations.

I have recorded or observed fledglings and juveniles giving the following vocalizations: the subsong (fledglings only), the rehearsed song (juveniles only), the two warning calls buzz and tek, the fight call scri, the two location calls chuck (fledglings only) and rack (juveniles only), and a begging call dzip.

### The Subsong

Lanyon (1960) designates the subsong as the first stage in the development of the adult or primary song.

#### Physical Description of the Subsong

The subsong sounds like low warbling. The complex syllables vary within the utterance and are noisy (Fig. 10). Four sonograms are analyzed from subsongs of two groups of fledglings 23 and 36 days old. The syllable length varies from 0.06 to 0.8 second within the utterance. The frequency ranges from 300 to 3,200 cycle/sec, and the number of syllables per second varies from 5.5 to 7.

The length of the utterance, measured by a stop watch from six random recordings, varied from 1.1 to 3.7 seconds.

Behavior Associated with the Subsong

I have not been able to associate stimuli with the occurrence of the subsong, and I believe the subsong to be practice for the adult song. During the subsong the fledgling does not perch in a conspicuous place as the adult usually does. The intensity of the subsong is less than that of the primary song. The formant pattern, syllable length, and frequency range of the subsong changes within the utterance, whereas it does not in the adult song.

Lanyon (1960) says the subsong is of greater duration and generally has a higher frequency range than the definitive primary song. I do not have a sufficient number of sonograms to substantiate these aspects of the subsong. Lanyon also states that call-notes are usually included within the subsong. Although call-notes may be given immediately before or after the subsong I have not seen specific call-notes on the sonograms.

## The Rehearsed Song

Lanyon (1960) states the rehearsed song is the next stage after the subsong in the development of the primary song.

Physical Description of the Rehearsed Song

Five sonograms of the rehearsed song are analyzed. The syllables are complex, noisy and constant within an utterance. Four of the five songs were not distinguishable from the patterns of the adult song. The syllables vary from 0.09 to 0.13 second and three to eight syllables are given per second. The frequency ranges from 200 to 3,700 cycle/sec. The utterances, measured by a stop watch from nine random recordings, vary from 1.0 to 5.0 seconds.

Behavior Associated with the Rehearsed Song

I observed the songs given in flocks of foraging juveniles during August, 1968. The rehearsed songs were associated with squabbles of birds foraging together, a chase, and scri call. I have observed it given at other times, but I do not know the behavior associated with these rehearsed songs.

Note the similarity of the rehearsed song (Fig. 11) and the adult song (Fig. 3E). The rehearsed song here is designated as such mainly on the basis of the immature age of the bird. Lanyon (1960) says the primary song is typically developed during the first winter or early spring.

## Dzip

Although I heard this begging call most often from fledglings, I recorded it at a nest when the nestlings were about ready to fledge.

### Physical Description of the Dzip

Five sonograms are used for the analysis. The syllable is simple and noisy, and on regular sonograms appears much like the adult buzz call. The dzip is a stereotyped vocalization. Usually two or three are uttered at a time. The syllables vary from 0.04 to 0.06 second, and have a frequency range from 85 cycle/sec to about 12,000 cycle/sec. A sonogram (Fig. 14B) showing a frequency range to 16,000 cycle/sec has a cross type pattern. The horizontal of the cross is between 3,000 and 5,000 cycle/sec, and the main frequency range of the vertical is about 8,000 cycle/sec.

### Behavior Associated with the Dzip

The dzip is given as the parent approaches the fledgling to feed it. The fledgling crouches and flutters the wings during the call and feeding.

## Chuck

The chuck is probably used by fledglings as a means of identifying their position to their parents. The adults then go to the young birds.

Physical Description of the Chuck

The syllable is simple, and looks much like the adult tek. The length of the syllables ranges from 0.02 to 0.03 second in the four sonograms I analyzed (Fig. 12). The syllables are given at the rate of about three per second. I was unable to obtain utterance length from the recordings because of extraneous noise. The frequency ranges from 85 cycle/sec to 5,000 cycle/sec.

Behavior Associated with the Chuck

The fledgling usually gives the chuck, and when the parent approaches the fledgling with food the chuck is replaced by dzip. I have recorded three times the parent giving a chuck, the fledgling then gives the chuck and the parent approaches to feed it. The chuck has been recorded from a nest containing young ready to fledge. It was possible to make only one sonogram of the adult chuck. It differs from the fledgling chuck only in the frequency range, which is from 85 cycle/sec to 1,000 cycle/sec.

## Scri

I observed the scri given by fledglings and juveniles during territorial disputes, and frequently when groups of juveniles were foraging together.

## Physical Description of the *Scri*

The *scri* syllable appears to be a stereotyped vocalization and no differences between the adult and juvenile *scri* were seen on the sonograms.

## Behavior Associated with the *Scri*

I often observed squabbles in groups of foraging juveniles. On one tape I recorded squabbles four times in nine minutes from a group of five juveniles. One juvenile usually flies at another and gives the *scri* call; a bird usually chases another only a few feet. A rehearsed song may be given by one or both of the birds, and they continue foraging in close proximity.

## *Buzz*, *Tek* and *Rack*

I observed *buzz*, *tek* and *rack* calls given by fledglings and juveniles during territorial disputes, and infrequently by juveniles during squabbles within foraging groups. I do not have sonograms of these calls.

## NESTLING VOCALIZATIONS

I recorded a total of five different calls from nestlings. The dzip and the chuck were usually given by nestlings ready to fledge (described above). The begging calls peep and cheep are heard most often. I recorded the distress call rap only once.

### Peep

#### Physical Description of the Peep

The peep call is associated with feeding. The analysis is based upon six sonograms made from calls given by nestlings about 13 and 18 days old. The syllables have a definite "musical looking" pattern. Unlike other Cactus Wren vocalizations, they contain no noise (Fig. 13). The syllables vary from 0.05 to 0.09 second in length, and the frequency ranges from 85 cycle/sec to about 5,800 cycle/sec.

All syllables I have seen on the sonograms are different, but form an obliquely up-and-down noise free pattern.

#### Behavior Associated with the Peep

I have heard the peep only from nestlings being fed by their parents.

## Cheep

The cheep is the loudest and most frequent call associated with feeding (Fig. 14). The four sonograms I analyzed were made from vocalizations of nestlings about 13 days old.

### Physical Description of the Cheep

The syllable length varies from 0.08 to 0.11 second, and about three syllables are given per second. The frequency ranges from 85 to 12,000 cycle/sec. The syllable is very noisy and looks much like the dzip call on sonograms ranging to 4,000 cycle/sec, but the main energy is concentrated below 1,000 cycle/sec.

### Behavior Associated with the Cheep

The cheep and the peep were given intermittently during feeding. I heard them every time the nestlings were fed, except in those cases where the intense buzz of the parent seemed to stop the nestling vocalizations.

## Rap

I have recorded the distress call rap only once when I handled a nestling.

### Physical Description of the Rap

Four rap syllables were uttered in succession. All syllables were not included on the sonogram, but the two

analyzed were 0.32 and 0.38 second long (Fig. 15). The frequency ranged from 85 to 9,000 cycle/sec.

Behavior Associated with the Rap

I believe the stimulus for the rap to be extreme fear, but I have handled many nestlings and they did not vocalize.

## DISCUSSION

I have found that the Cactus Wren has nine basic categories of vocalizations: the song, and eight types of calls. Confusing terminology makes it difficult to compare the size of the vocal repertoire with other birds. Bremond (1963) cites the numbers of acoustic signals in the repertoire of a variety of birds. He lists from nine acoustic signals for Corvus monedula to 25 signals for Sylvia communis, but the reader is in doubt if "acoustic signals" refer to the basic categories of vocalizations. If one considers the number of acoustic signals for the Cactus Wren to be the main categories of vocalizations, then the Cactus Wren has a small repertoire of nine vocalizations. However, if the variations of the song and call-notes are included as separate acoustic signals, then the repertoire would be much larger. Verner (personal communication) recognizes a minimum of 12 different categories of vocalizations for the Long-billed Marsh Wren. Armstrong (1955) lists 13 categories of vocalizations for the Winter Wren.

I have recorded 32 different songs from the Cactus Wren, including 14 different songs from the same bird. It is probable that each wren has a repertoire in excess of 14 different songs. Verner (personal communication) has

recorded 110 different songs from one Long-billed Marsh Wren, and Armstrong (1955) lists 11 different songs used by the Winter Wren. Borror (1956) reports 71 songs for the Carolina Wren recorded in three areas, Ohio, North Carolina, and Florida. Bent (1948) reports 36 different songs given by one Carolina Wren in one season.

Most vocalizations (the song, the buzz, the tek, the rehearsed song, the chuck, the dzip, and the cheep) are utterances composed of a series of like syllables. These utterances are not always the same and may vary almost every time they are heard. Thus the Cactus Wren has many different songs and several variations of each call-note. Since the behavior associated with the songs may overlap the behavior associated with the call-notes, I used a combination of physical characters to differentiate song from call-notes. There are many variations in the pattern of the complex syllable of the song. Utterances of songs with like syllable patterns have the same physical characters (syllable length, syllable rate, and frequency range). As the syllable pattern of the song changes the physical characters also change. The simple syllable pattern of each call-note varies little from one utterance to the next, but the physical characters (syllable length, syllable rate, and frequency range) may change.

From the data I have collected, I believe that a change in stimulus may result in variation of the syllable

pattern of the song, but cause variation in the physical characters of the call-note.

The concept that variations of the song may be used in different contexts is not new. Armstrong (1955) found that 11 songs of the Winter Wren are used in different situations, and Kendeigh (1941) noted a different behavior associated with each of three songs of the House Wren. Ficken and Ficken (1967) state that Golden-winged Warblers vary the number of notes in the song according to the context. In addition to the primary song they report two secondary songs for the Golden-winged Warbler and a flight song for the Blue-winged Warbler.

Lanyon (1960) cites studies on six species of passerine birds for which evidence has been found for the development of young bird calls into adult vocalizations. Although I do not have sonograms to demonstrate the transition of nestling, fledgling, and juvenile calls into adult vocalizations, the similarity in structure of some of the vocalizations is striking. The nestling cheep is very similar to the fledgling dzip, and both are similar to the adult buzz. The fledgling chuck resembles the adult chuck and tek. Parts of the adult song syllables suggest the nestling peep and the fledgling dzip. Further study of the Cactus Wren may reveal the transition of the calls of young birds to adult calls. It is possible that the acoustics and the sound in the Cactus Wren's environment or the morphology

of the vocal apparatus limits the number of different syllable structures in the vocalizations. The scri, tek, buzz, dzip, chuck, and the cheep all appear to be variations in syllable length and rate of a single noisy syllable which looks like a vertical stripe on the sonogram. All are structured for location of the calling bird and may have value in being location calls.

Location of sounds can be achieved in three ways: binaural phase differences, binaural intensity differences, and binaural time differences. Marler (1956a) describes for the Chaffinch an alarm call that can be easily located and one which is difficult to locate. The factors determining the ability to locate a sound can be seen on sonograms. A broad frequency spectrum indicates the possibility of the sound containing information for binaural phase and intensity differences. The repetition of sound separated by stops in sound energy indicates the sound contains information for determining binaural time differences.

I calculated the theoretical highest frequency that could be used by the Cactus Wren for phase location and correlated this with frequencies seen on the sonograms. Also, I investigated the possibility of binaural intensity and time differences being used by the Cactus Wren.

I assumed that the most efficient frequencies for location sound by phase differences are those in which the crest of the wave is at one tympanic membrane while the node

of the wave is at the opposite tympanic membrane. (The crest of the wave is that part of the wave which contains the greatest pressure or greatest compactness of air molecules. The lowest portion of the phase has the least pressure.)

The theoretical highest frequency that could be used for phase location is that frequency which has a wave length twice the distance between the bird's two tympanic membranes.

By using the formula $V = F/\lambda$ (V = velocity of sound in air, F = frequency of the sound, and $\lambda$ = the wave length of the sound), I calculated the highest theoretical frequency for phase location. The velocity of sound used was calculated on the basis of average daytime temperatures for Tucson, Arizona since 1900. Humidity changes have a negligible effect on the velocity of sound. I determined the wave length by measuring the distance between the tympanic membranes on five skulls of Campylorhynchus brunneicapillus and doubling that measurement to produce the theoretical wave length twice the distance between the ears.

$$\text{frequency} = \frac{\text{velocity of sound}}{\text{wave length}}$$

$$\text{frequency} = \frac{345.62 \text{ m/sec}}{.0312 \text{ m}} = 11{,}077 \text{ cycle/sec}$$

From these data I conclude that the Cactus Wren may use frequencies up to 11,077 cycle/sec for phase location.

Theoretically location by a difference of sound intensity between the two ears occurs at wave lengths smaller than the bird's head. It is at these frequencies that the head serves as a sound block and greatly decreases the intensity at the ear opposite the sound source.

I have not found frequencies above 12,000 cycle/sec in Cactus Wren vocalizations. Since the theoretical highest frequency for phase location is near the highest frequency observed for the Cactus Wren, I propose that binaural intensity differences play little or no role in Cactus Wren location.

The Cactus Wren calls cheep, chuck, dzip, scri, buzz, tek, and the song are structured to give excellent location by time difference. The repeated breaks between the syllables or within the syllables would allow the sound to arrive at the ear nearest the sound source before it arrives at the ear furthest from the source. How rapidly the Cactus Wren can analyze separate sounds is unknown. Thorpe (1961) says there is evidence that birds can analyze sounds about ten times faster than humans and that humans fail to count more than three impulses delivered less than 0.1 second apart. If the Cactus Wren could analyze sounds 0.01 second

apart, it could be analyzing every vertical spike in the scri call and be obtaining much information from other calls such as parts of the song syllable.

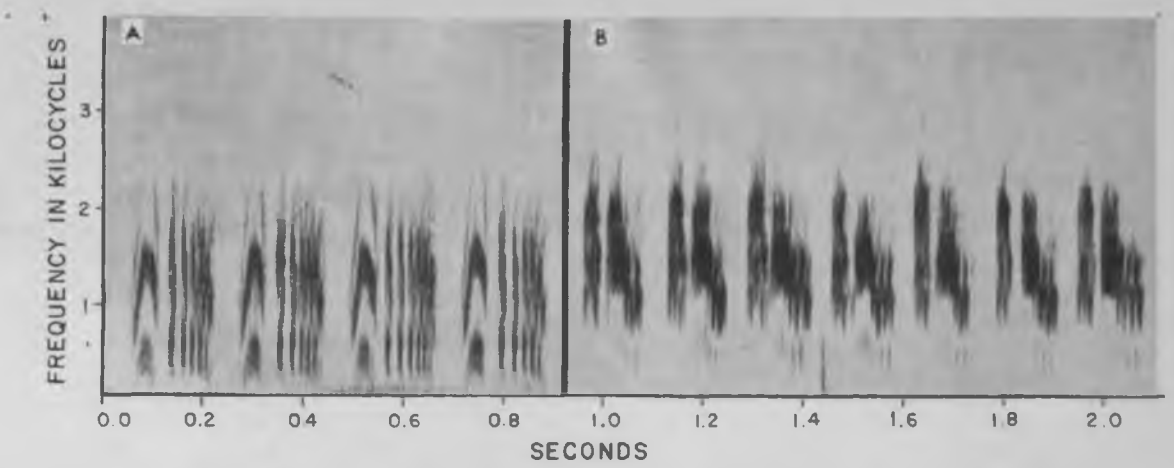


Figure 1. Sonograms of songs, examples A and B.

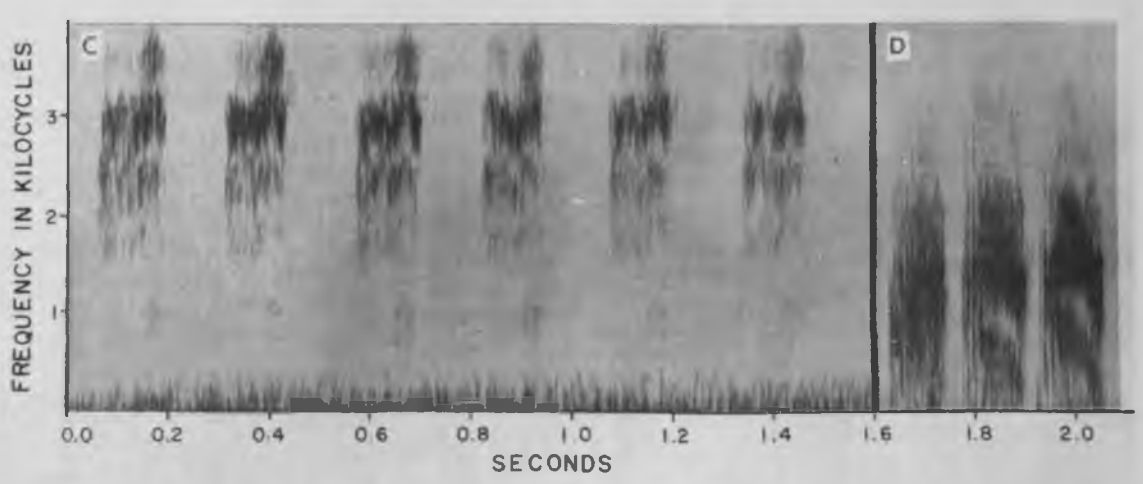


Figure 2. Sonograms of songs, examples C and D.

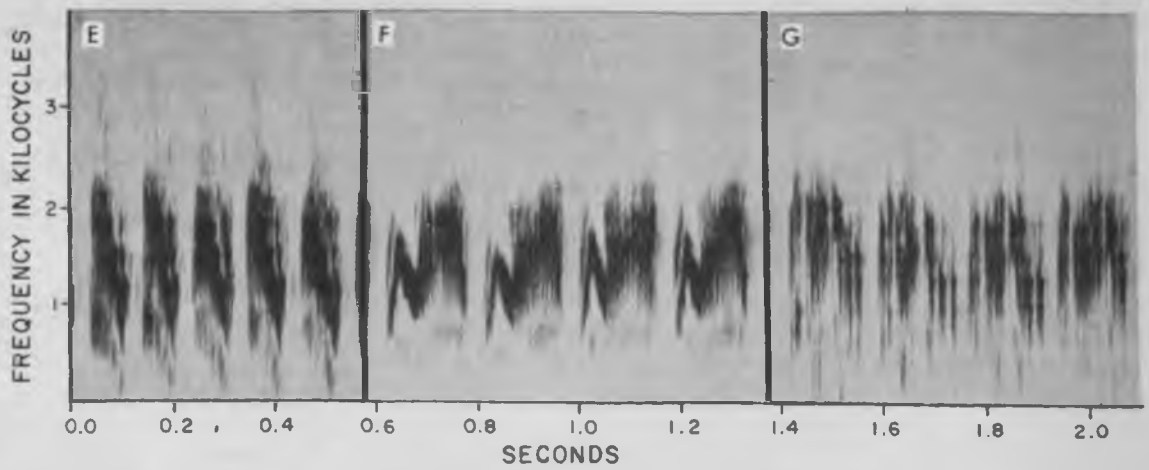


Figure 3. Sonograms of songs, examples E, F, and G.

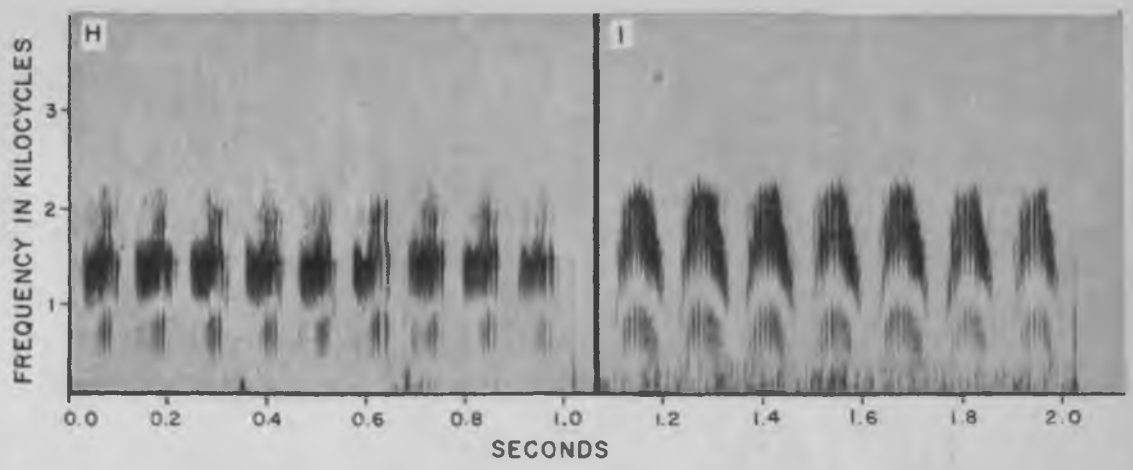


Figure 4. Sonograms of songs, examples H and I.

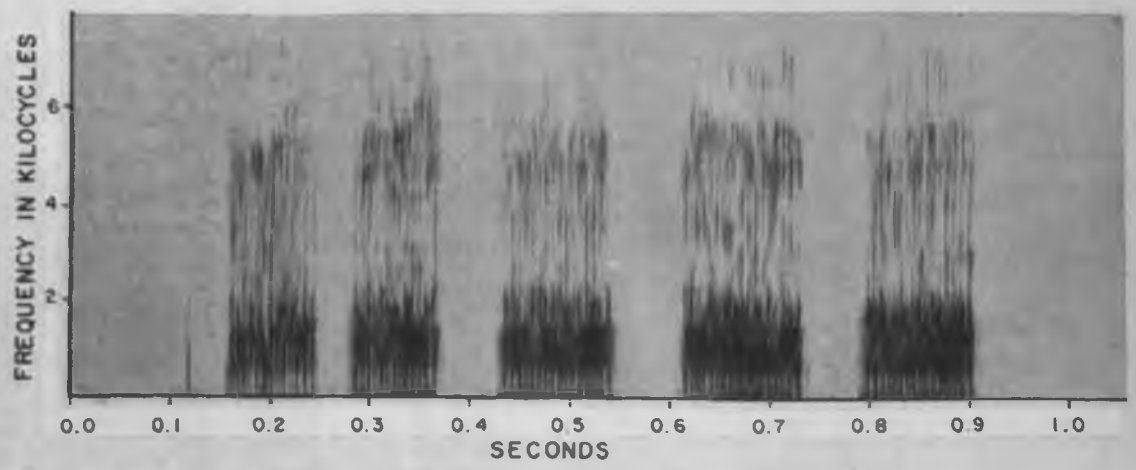


Figure 5. Sonogram of adult warning call buzz.

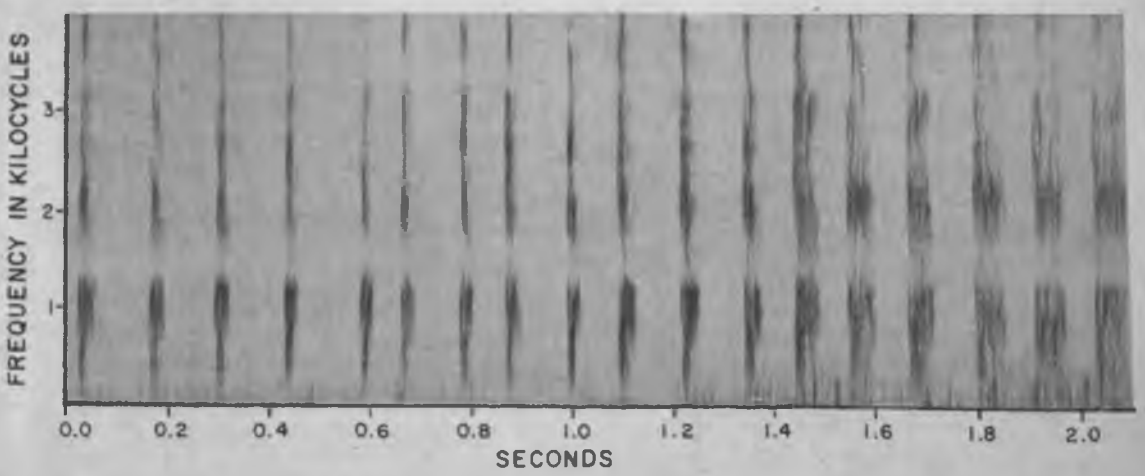


Figure 6. Sonogram illustrating transition of adult warning calls tek (left) to buzz (right).

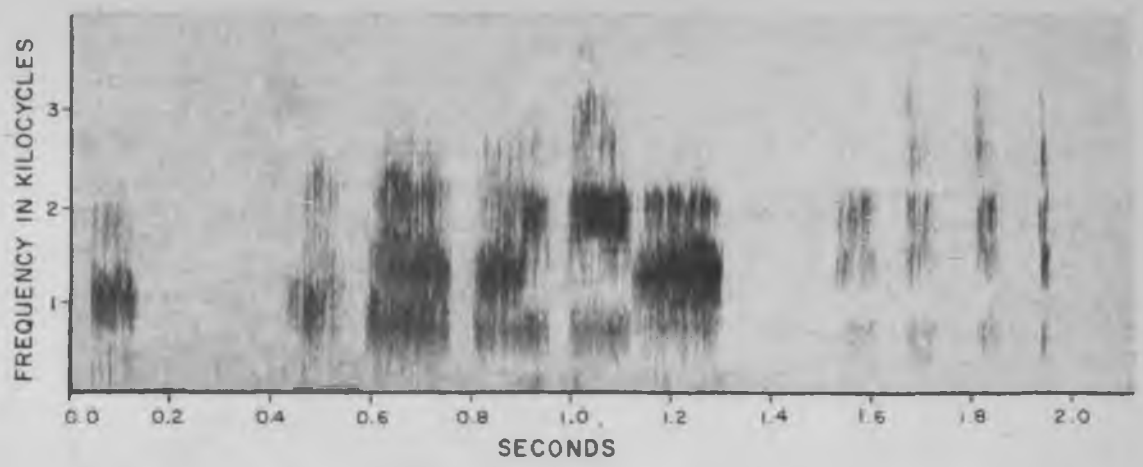


Figure 7. Sonogram of recognition call growl, example 1.

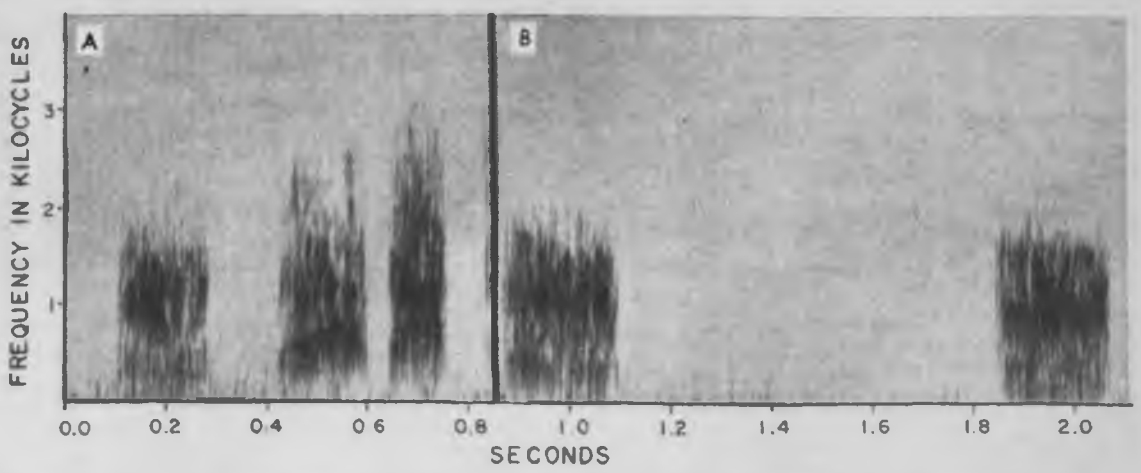


Figure 8. Sonogram of recognition call growl, example 2.

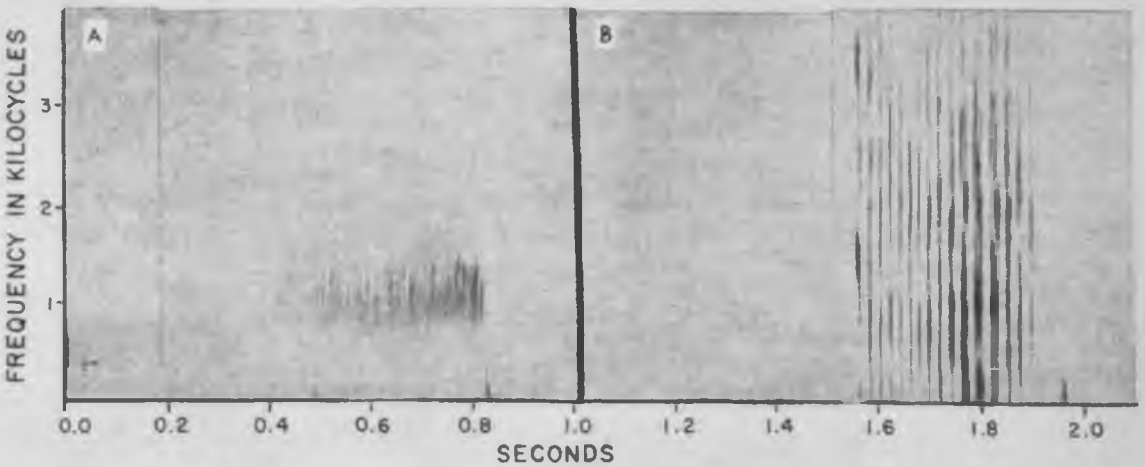


Figure 9. Sonogram of adult location call rack, A; sonogram of adult fight call scri, B.

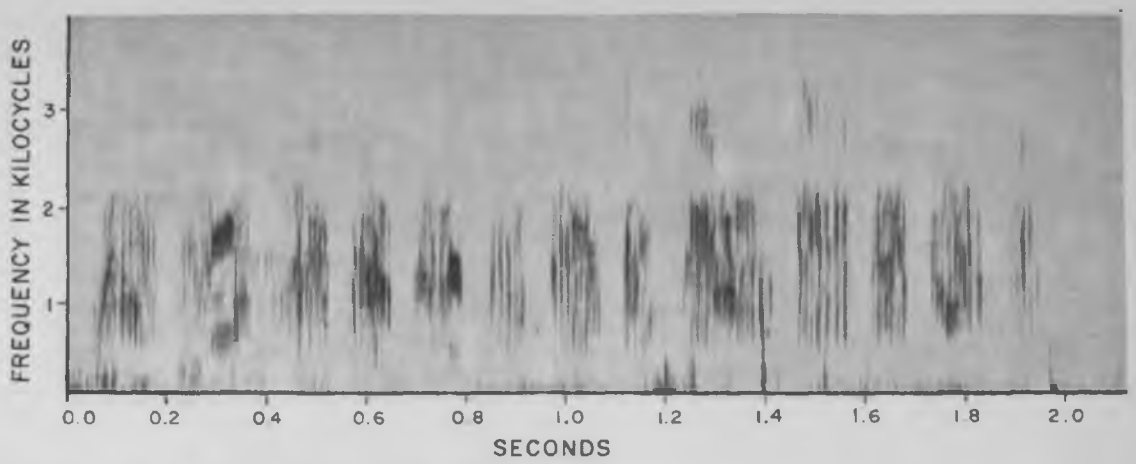


Figure 10. Sonogram of subsong.

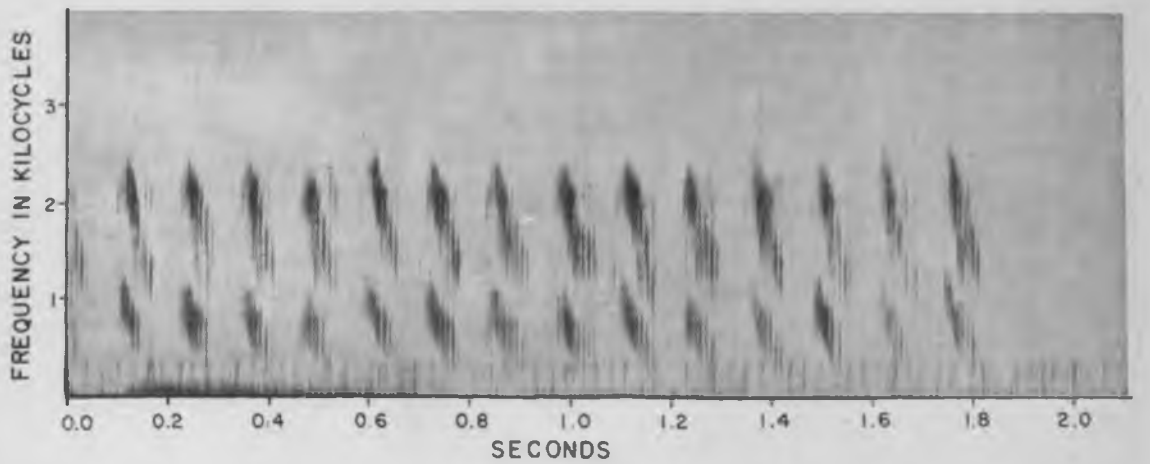


Figure 11. Sonogram of rehearsed song.

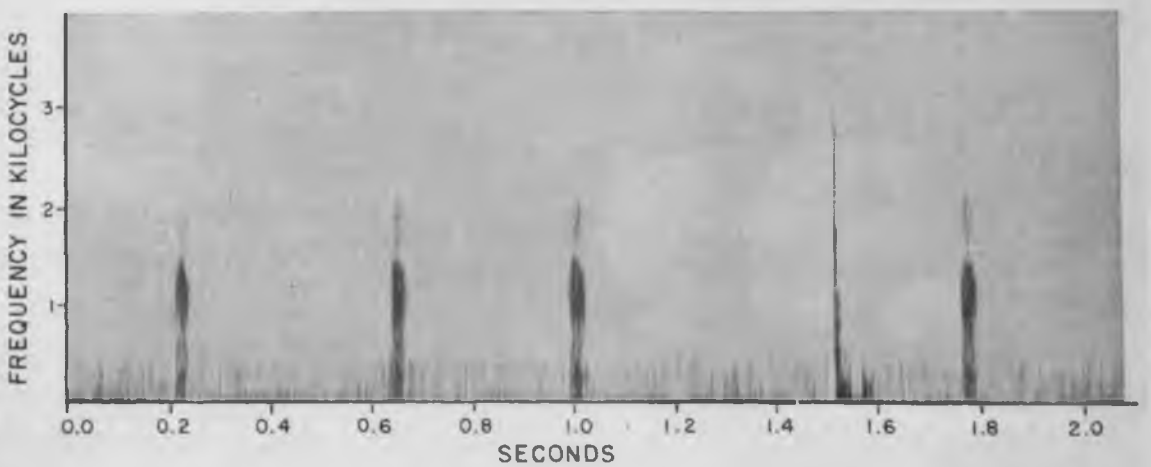


Figure 12. Sonogram of fledgling location call chuck.

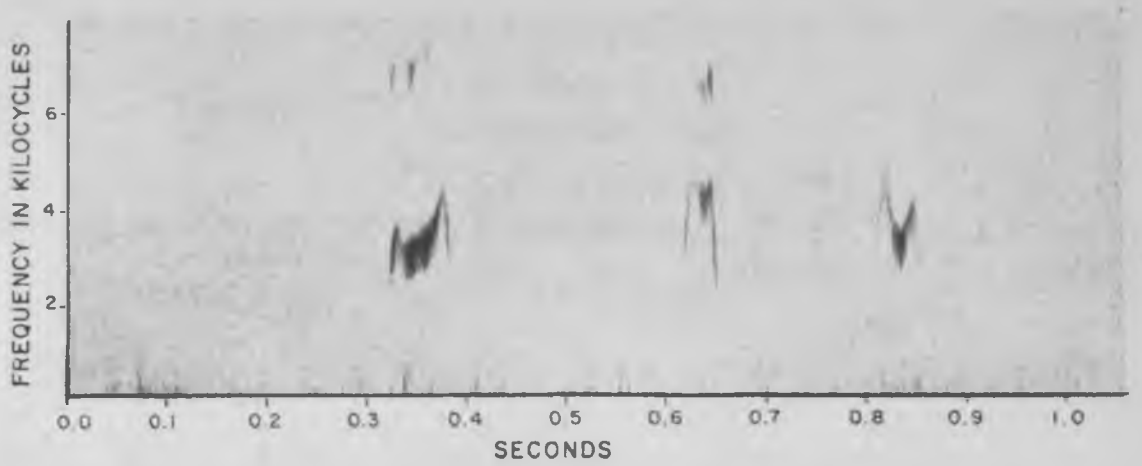


Figure 13. Sonogram of nestling begging call peep.

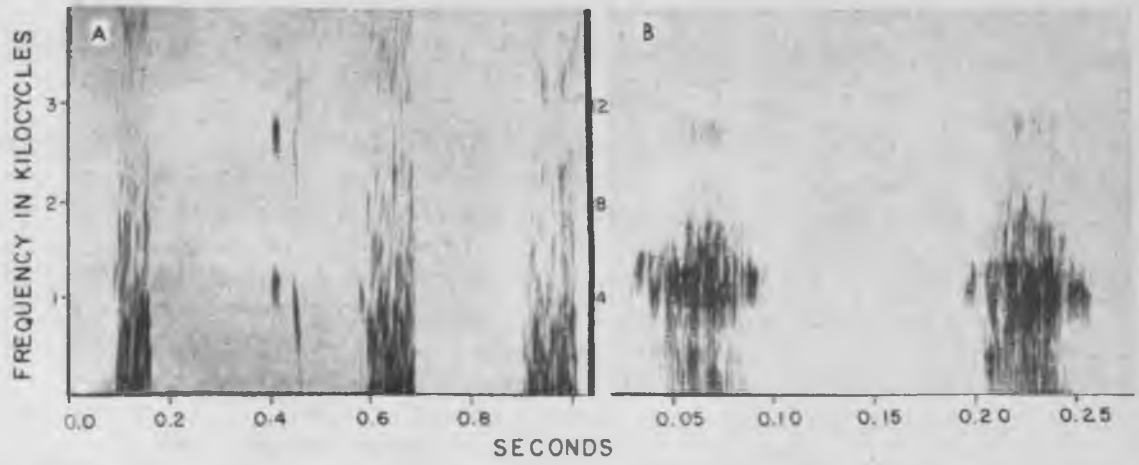


Figure 14. Sonogram of nestling begging call cheep, A; sonogram of fledgling begging call dzip, B.

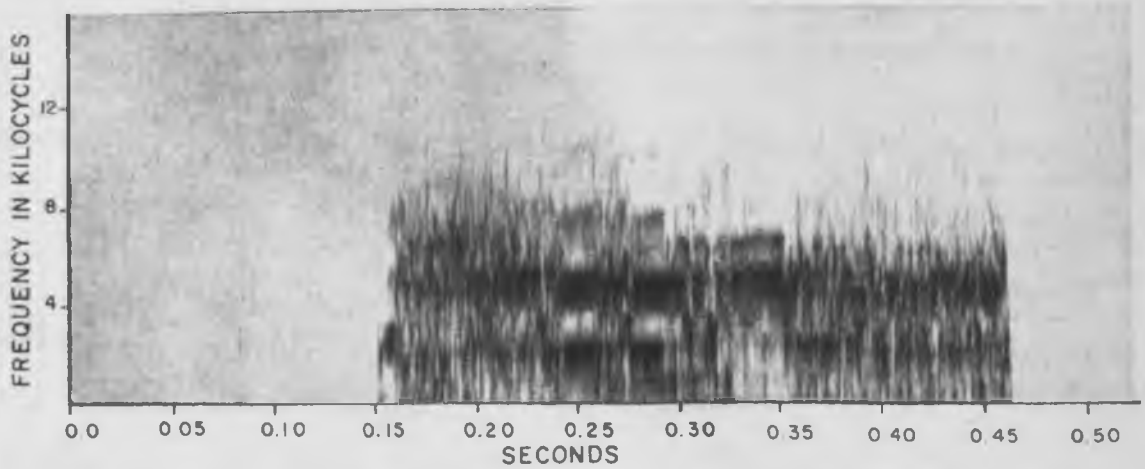


Figure 15. Sonogram of nestling distress call rap.

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