A SPECTROGRAPHIC ANALYSIS OF BURROWING OWL VOCALIZATIONS

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ONE of the first studies of the Burrowing Owl (*Speotyto cunicularia*) appeared almost 100 years ago (Coues 1874). Most of the many brief accounts published since deal with its food habits or are casual observations of behavior. Recently Thomsen (1971) and Coulombe (1970, 1971) published major studies of this species, Thomsen on its food habits, behavior, and population dynamics, Coulombe on its physiological attributes, food habits, behavior, and seasonal movements. Neither author spectrographically analyzed any of the vocalizations they described.

The main purpose of this study is to analyze Burrowing Owl vocalizations, the first such analysis of any North American member of the Strigiformes. Also Burrowing Owl vocalizations, primarily song, are compared to information gathered from passerines to illustrate that other orders of birds may follow the general rules by which passerine song appears to be structured.

METHODS AND MATERIALS

I studied a population of 15 breeding pairs of Burrowing Owls and their offspring from 5 May 1970 to 20 May 1971 near Albuquerque, Bernalillo County, New Mexico. Observation time totaled over 400 hours. Most observations were made from a car or on foot and were aided with 7 × 50 binoculars and a 30 × spotting scope. A portable blind was used for close observations and for recording vocalizations. As lights disturbed the owls, none were used.

The study area contained two concentrations of nesting holes 3 miles south of Albuquerque at an elevation of 5,300 feet. One was a 1.8-mile-long section at Tijeras Arroyo, the second a ½-mile-long section where a railway cut through a hillside. The two sites were ½-mile apart and the intervening land served as mutual foraging ground.

Vocalizations were recorded with a Uher 4000 Report-L Tape Recorder and Uher M-514 microphone at 7-½ ips. A 24-inch parabolic reflector sometimes was used. Spectrograms were produced with a Kay Electric Company Sonagraph (6061-B) equipped with an Amplitude Display Unit (6076-C). Data for time analysis came from frequency-time spectrograms, using wide band-pass setting. Those analyzed for amplitude were produced at a narrow band-pass setting with the Amplitude Display Unit. Frequency analysis came from frequency/time spectrograms at a narrow band-pass setting.

A spectrogram using a Sona-Marker Time Marker and frequency marker units was used as a template for measuring various parameters of the vocalizations accurately. From this a transparency with frequency and time increments was produced and used as an overlay to measure spectrogram prints.

Of 15 breeding pairs, 9 females and 9 males were color-banded for individual recognitions. At least one adult of each pair was banded at all but two burrows. One

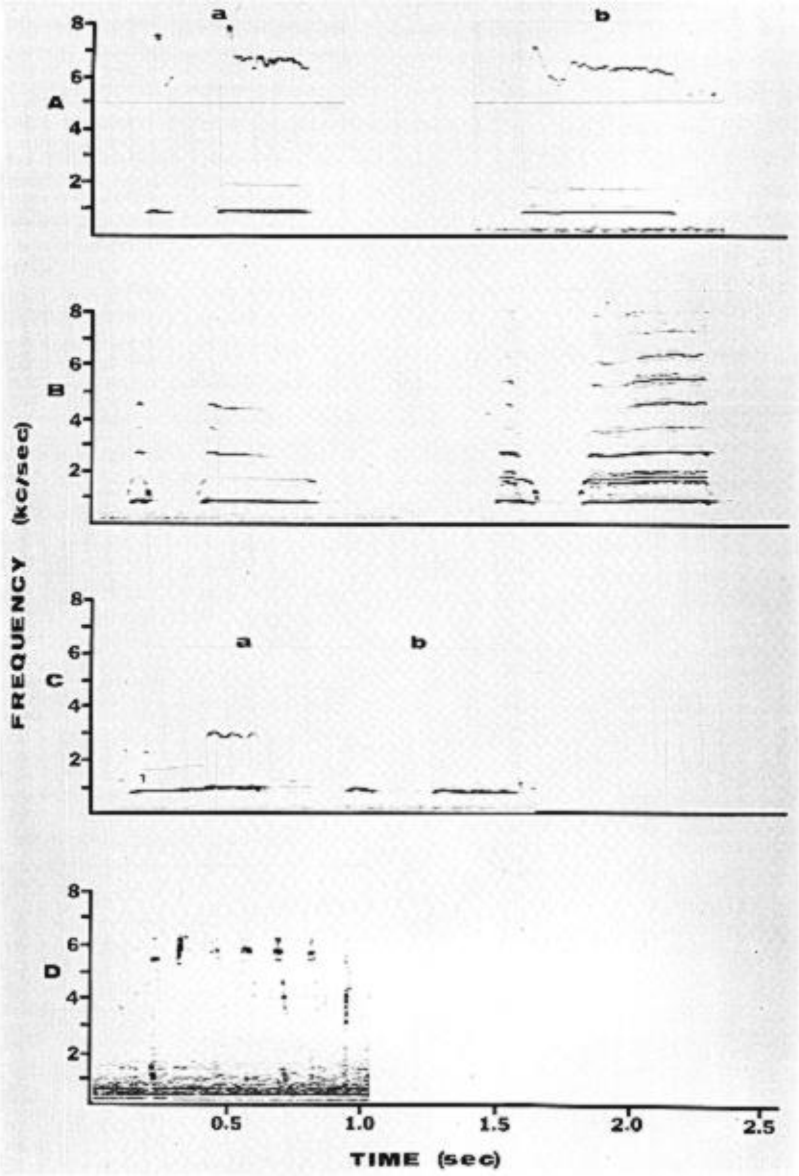

Figure 1. Spectrograms of vocalizations of adult male Burrowing Owls. A. a, Primary song with an amplitude display; b, one-note song with an amplitude display. B. Primary songs showing harmonics. C. a, Male warble; b, song during copulation. D. Tweeter call.

unmated adult and 48 young also were banded. Each owl received a U. S. Fish and Wildlife band and a two-color combination of red, white, green, or yellow color bands. Owls were captured by placing Havahart traps within the burrow mouth as described by Martin (1971). All adult owls were sexed by presence or absence of a brood patch and by feather coloration and confirmed later by their behavior in the field.

ADULT VOCALIZATIONS

Coo coo.—This is the primary song of the Burrowing Owl. Only males were seen giving it. It functions in pair formation, precopulatory behavior, and territory defense. The song consists of two notes of almost equal frequency, with the second note being longer than the first (Figure 1A). The minimum and maximum frequency of the first note varies from 0.05–0.90 kc/sec ($\bar{x}$ = 0.729, SD = 0.075, N = 24) and 0.08–1.3 kc/sec ($\bar{x}$ = 1.02, SD = 0.146, N = 24). The minimum and maximum frequencies of the second note vary from 0.5–0.9 kc/sec ($\bar{x}$ = 0.733, SD = 0.082, N = 24) and 0.8–1.3 kc/sec ($\bar{x}$ = 0.992, SD = 0.138, N = 24). The duration of the first note varies from 0.05–0.19 sec ($\bar{x}$ = 0.104, SD = 0.032, N = 24). The duration of the second note varies from 0.33–0.55 sec ($\bar{x}$ = 0.453, SD = 0.068, N = 24). The interval between the notes varies from 0.13–0.38 sec ($\bar{x}$ = 0.189, SD = 0.049, N = 24).

The song is complex because of its many harmonics (Figure 1B). The harmonics are relatively undistorted and the alternate ones are stronger than the others, thus imparting a pure and musical tone to the song (Thorpe and Lade 1960). Occasionally while the male sang, he gave only one note (Figure 1A). This note agrees with the characteristics of the first and second notes of the complete primary song without a time interval between them.

Smack.—This call is given by female Burrowing Owls during copulation (Figure 2A). It consists of one to many down-slur notes. The mean minimum and maximum frequencies are 0.74 kc/sec (SD = 0.063, N = 25) and 1.98 kc/sec (SD = 0.316, N = 25). The mean duration of the notes is 0.050 sec (SD = 0.062, N = 25). The mean duration between notes is 0.206 sec (SD = 0.062, N = 25).

Tweeter.—This multinoted call is given by the male near termination of copulation (Figure 1D). It is not always given, but when it is, it always follows the male's song during copulation. The notes of the call consist of a multitude of long up-and-down slurs, beginning and ending at a mean of 3.3 kc/sec (N = 5). The notes peak at a mean maximum frequency of 6.7 kc/sec (N = 5). The mean duration of the notes is 0.08 sec (N = 5) and the mean duration between the notes is 0.05 sec (N = 4).

Song during copulation.—Males give one or two primary songs during copulation (Figure 1C). The call is two-noted and has the same char-

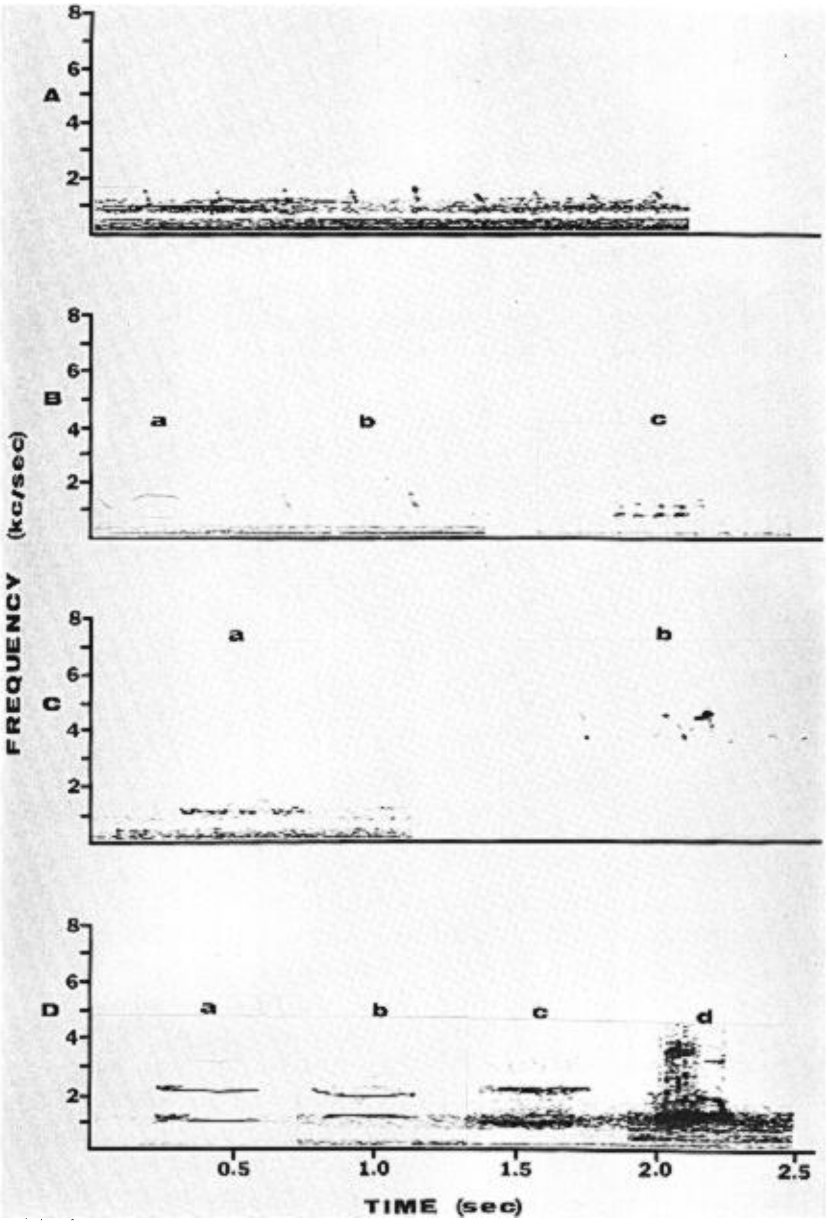

Figure 2. Spectrograms of vocalizations of adult male and female Burrowing Owls. A. Smack call of female during copulation. B. a, A male's short one-noted song during copulation; b, two smack calls of a female; c, a female rattle call. C. a, A female copulation warble; b, a female defense warble. D. a–d, Female eep call (a) grading into rasp call (d), (b) and (c) intermediate forms.

acteristics as the primary song. In certain instances only a single note is given (Figure 2B). The frequency of this note agrees with that of the primary song, but the note may be greatly shortened.

Rasp.—This call is given primarily by the adult female (Figure 5A, 5B). She gives it when distressed, when a predator is near the burrow, upon receipt of food from the male, while presenting food to the young, as the male sings, and when begging for food. The call often appeared to stimulate the male to begin foraging. Males occasionally gave the call when presenting food to the female or young.

The minimum frequency varies from 0.5–1.0 kc/sec. The maximum frequency varies with the call's intensity, from about 3.5–6.6 kc/sec. The duration of the call is variable, but usually less than 1.0 sec.

Eep.—This call is given by the female as the male sings (Figure 2D). It may grade into the rasp call (Figure 2D), and therefore, is thought to be associated with food begging or precopulatory behavior. The minimum frequency is about 0.96 kc/sec ($\bar{x} = 0.98$, $N = 3$). The maximum frequency of the fundamental is about 1.3 kc/sec ($\bar{x} = 1.2$, $N = 3$). The duration of the call is from 0.29–0.40 sec, although this is highly variable and may be greatly extended if the rasp component is present and included in the measurements. The call, apparently when spread over a wider frequency length, will then form the rasp call.

Female defense warble.—This call is given by the female while defending her burrow against conspecific females (Figure 2C). It appears to have a very irregular pattern and is relatively high in frequency, with minimum and maximum frequuencies of 3.5 and 4.1 kc/sec ($N = 1$). The call's duration appeared highly varible.

Female copulation warble.—Female Burrowing Owls also have a warble call infrequently given during copulation (Figure 2C). Only one such call was recorded. It has a minimum frequency of 1.5 kc/sec and a maximum frequency of 2.0 kc/sec. The duration of the call is about 0.47 sec.

Male warble.—Males may add an undulation to the end of their song during copulation. This produces a warbling sound (Figure 2C). The call has the same characteristics as the primary song, but at the end undulates between 0.6 and 1.0 kc/sec.

Rattle.—The female gave this call while I played recordings of the primary song (Figure 2B) in the male's absence. In most cases the males quickly returned to their burrows and assumed a defensive posture. It could not be determined, because of the poor quality of rattle recordings that I played back, whether the female call or my primary song recordings caused the males to return. The minimum and maximum frequencies of

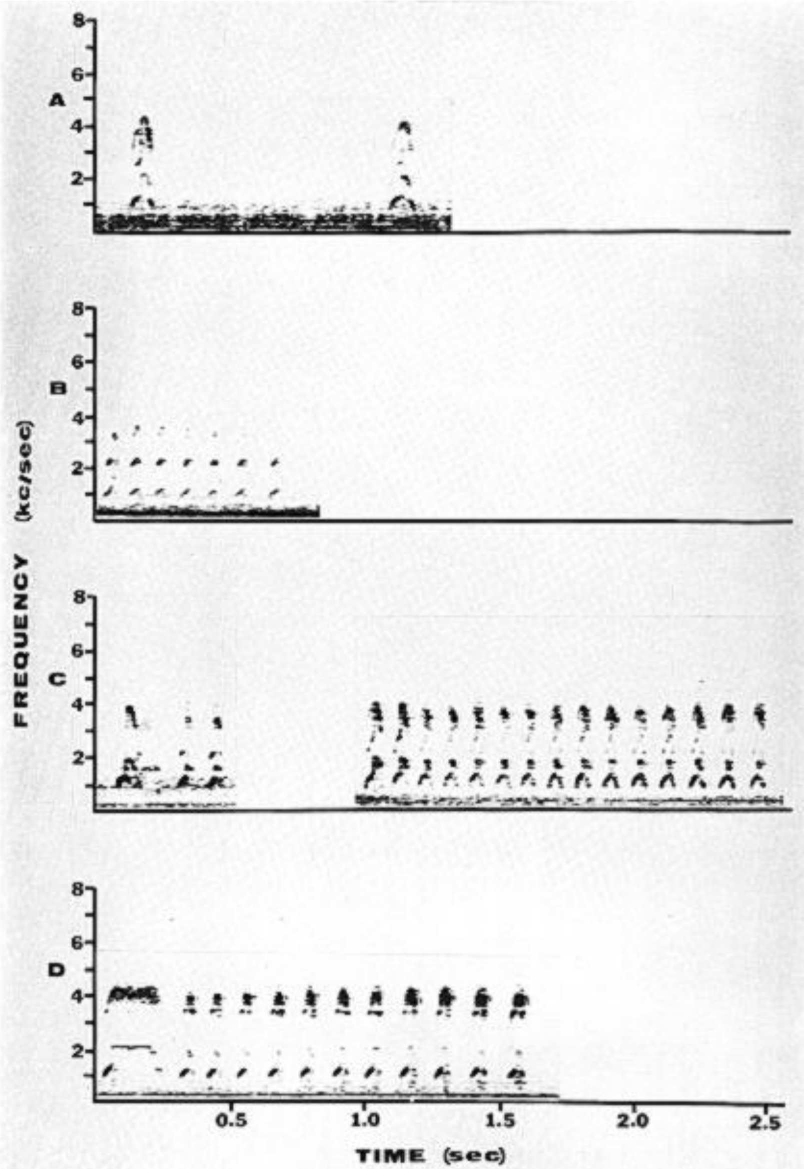

Figure 3. Spectrograms of predator defense call of adult Burrowing Owls. A. Two chuck calls. B. Typical 7-noted chatter call. C. Three- and 15-noted chatter calls demonstrating plasticity of call. D. Twelve-noted chatter call exhibiting an extended first note.

the call are 0.7 kc/sec and 1.7 kc/sec. The duration of the notes and the interval between them is 0.04 sec (N = 5).

Chuck, chatter, and scream.—These calls are closely related and discussed together. All are given by both males and females as warning calls or while mobbing.

The chuck (Figure 3A) is a single-noted, low-level warning call; it may be associated with the owl's bowing display. It consists of a gradual upward slur from 0.867–1.5 kc/sec, a sharp up-slur to a mean of 2.37 kc/sec, and a down-slur to about 0.867 kc/sec. The note's duration varies from 0.08–0.10 sec ($\bar{x}$ = 0.09, N = 3). The note contains at least three harmonics. Its structure makes it sound as though it consisted of two notes, one low and one high-pitched.

The chatter (Figure 3B, 3C) can best be described as a series of shortened chucks. Some authors (Thomsen 1971, Coulombe 1971) have postulated that the call has a basic number of notes. I have not found this to be the case. The chatter may consist of from 3 to at least 15 notes (Figure 3C), with 5–7 notes being most common (Figure 3B). A greater number of notes indicates a higher level of agonistic behavior by the owls. The call usually has an extended first note (Figure 3D), which has mean minimum and maximum frequencies of 0.875 kc/sec (SD = 0.129, N = 4) and 2.15 kc/sec (SD = 0.153, N = 4). The mean duration of the note is 0.9 sec (SD = 0.408, N = 4). The remaining chuck notes have mean minimum and maximum frequencies of 0.865 kc/sec (SD = 0.344, N = 66) and 2.0 kc/sec (SD = 0.003, N = 66). The mean duration of the chuck notes is 0.062 sec (SD = 0.003, N = 63) and the mean interval length between them is 0.064 sec (SD = 0.089, N = 60).

The scream call indicates the highest degree of threat or agonistic behavior the owls express. It may be given by itself, within the chatter call, or, most commonly, by replacing the first note of the chatter call (Figure 4A). The mean minimum and maximum frequencies of the scream are 0.10 kc/sec (SD = 0.000) and 5.3 kc/sec (SD = 0.02, N = 5). The duration of the call is highly variable; it may be as short as a chatter note or as long as 1.0 sec. The call itself appears to be produced by spreading the energy of the harmonics of the single note over a broader frequency length.

JUVENILE VOCALIZATIONS

Eep.—This call, given only by distressed young 2–4 weeks old when handled or trapped (Figure 4B), appears to serve as a low-intensity alarm call, but may also function as a hunger call. It is given at a low intensity and can be heard only a few feet. The call may, when the bird becomes more distressed, grade into the juvenile rasp call (Figure 4C). The eep

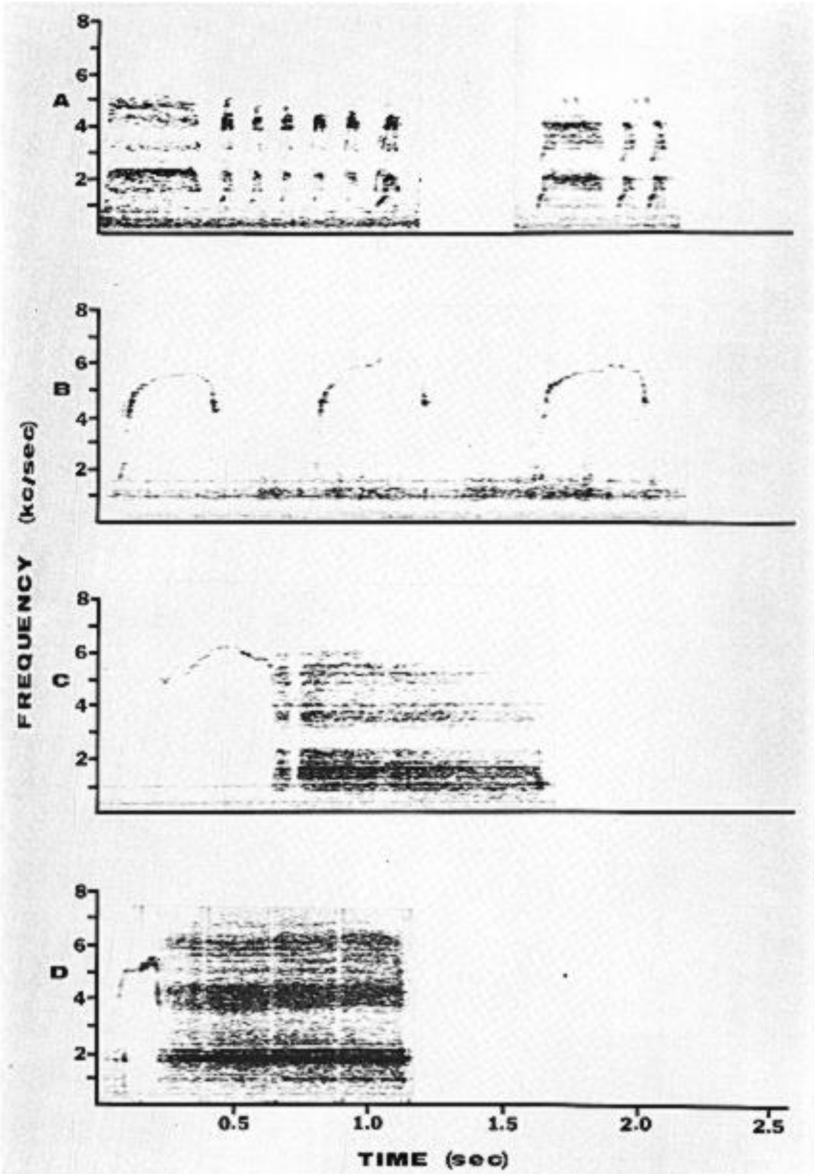

Figure 4. Spectrograms of vocalizations of adult and juvenile Burrowing Owls. A. Scream call (first note) followed by chatter calls. B. Juvenile eep calls. C. Juvenile eep call grading into rasp call. D. Compressed juvenile eep call grading into rasp call.

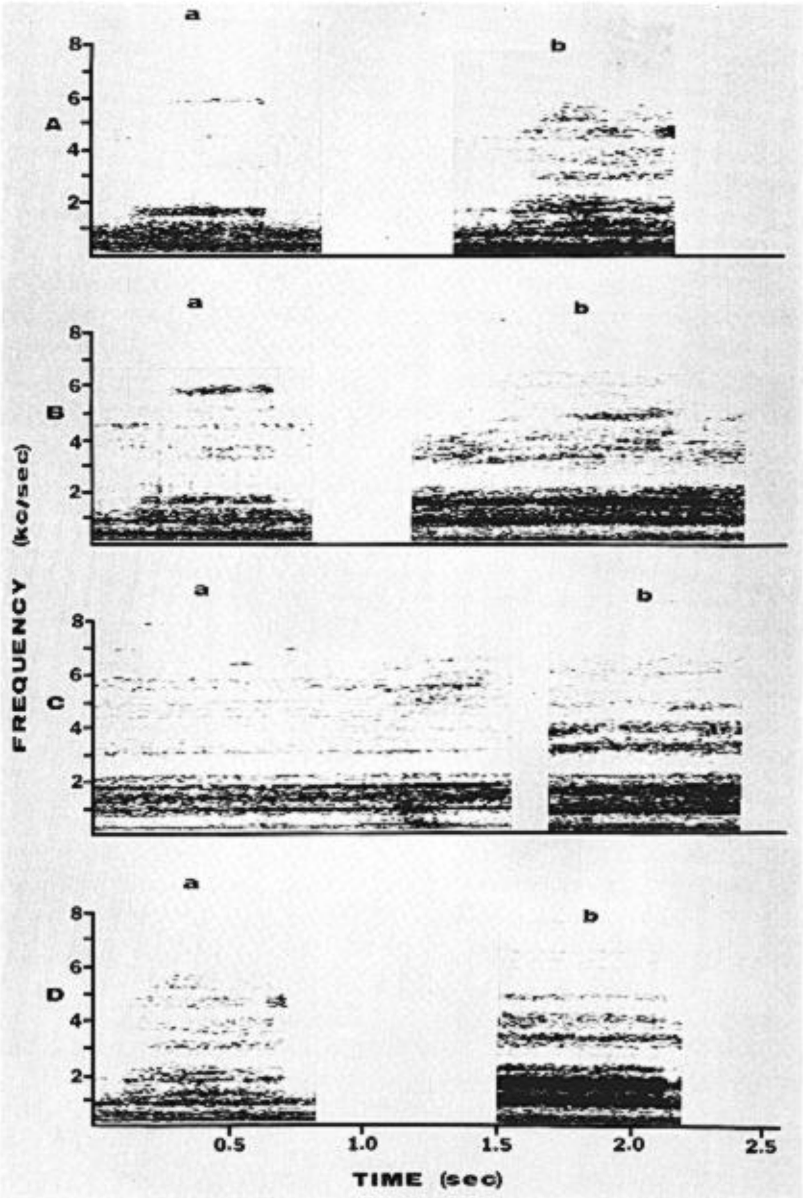

Figure 5. Spectrograms comparing rasp call of adult and juvenile Burrowing Owls and juvenile rattlesnake rasp calls with rattlesnake rattles. A. a, Adult female low-intensity rasp call; b, juvenile low-intensity feeding rasp call. B. a, Female feeding rasp call; b, rattlesnake rattle. C. a, Juvenile feeding rasp call; b, rattlesnake rattle. D. a, Juvenile rattlesnake rasp call; b, rattlesnake rattle.

call up-slurs from 0.75 kc/sec ($\bar{x} = 0.833$, SD = 0.076, N = 3) to a high of 6.7 kc/sec ($\bar{x} = 6.1$, SD = 0.551, N = 3), then down-slurs to a low between 3–4 kc/sec. The mean duration of the call is 0.46 sec (SD = 0.056, N = 3). The call is given at varying rates and follows no observable pattern.

Rasp.—This is a hunger call given by the young (Figure 5A, 5C). It appears to stimulate the male to begin foraging. It also is given upon receiving food. The minimum and maximum frequencies vary from 1.0–1.5 kc/sec ($\bar{x} = 1.3$, N = 3) and 5.8–6.0 kc/sec ($\bar{x} = 5.9$, N = 2). The duration of the call is highly variable.

Rattlesnake rasp.—This call is given by the young when severely distressed, as when cornered by a predator. It serves as a threat display (Figure 5D). It is widely stated that when given from inside a burrow, it closely resembles a rattling rattlesnake (Bent 1938, Coulombe 1971). The female owl also is supposed to give this call. Its description is the same as contained within the adult rasp call descriptions. The minimum and maximum frequencies of the juvenile rattlesnake rasp vary from 0.7–1.0 kc/sec ($\bar{x} = 0.85$, N = 4) and 6.0–6.6 kc/sec ($\bar{x} = 6.4$, N = 4). The duration of the call is variable.

Snap.—One other audible display given by the adult and juvenile birds is the snapping call. It is produced by snapping the mandibles together and appears to be common among most owls. It serves as a low-level protest or threat display.

Rattlesnake Rattles

Three spectrograms were produced of the rattle sound produced by prairie rattlesnakes (*Crotalus viridis*) (Figure 5B, 5C, 5D). The minimum and maximum frequencies vary from 0.1–0.7 kc/sec ($\bar{x} = 0.5$, N = 3) and 6.6–7.0 kc/sec ($\bar{x} = 6.6$, N = 3). Duration of the rattle was variable.

Analysis of Primary Song

Two songs from each of 12 male Burrowing Owls were analyzed. The parameters of the songs compared were the minimum and maximum frequency, duration of the notes, and the interval between the notes.

A three-way analysis of variance was performed with the frequency components. The factors considered for sources of variation were, A = among birds, B = among the first and second notes, and C = among the minimum and maximum frequency of the notes. The analysis demonstrated a significant difference ($P < 0.05$) in the songs among the 12 owls. This variance was caused by differences in both the minimum and maximum frequencies of the notes. The interaction AC, therefore, was also significant ($P < 0.05$).

A two-way analysis of variance was performed with the temporal components. The factors considered were, A = among birds, B = duration of the first note, second note, and interval between notes. No factors were significant ($P < 0.05$), indicating uniformity of temporal components.

Following the two-way analysis the temporal components were considered individually with a single classification analysis of variance. The analysis of the duration of the first and second note showed a significant added variance component among birds ($P < 0.05$). The analysis of the interval between the notes was not significant ($P < 0.05$).

By treating each temporal component as a separate entity, it appears that variance does occur between Burrowing Owls in the duration of their notes, but not the interval between their notes.

Correlation tests also were performed with the frequency data of all the primary songs. Values for minimum and maximum frequency of the first note were correlated with each other and correlated to the minimum and maximum frequency of the second note. The latter also were correlated with each other. The test demonstrated a strong positive correlation ($P < 0.05$) within the columns of minimum frequencies between the first and second notes and within the columns of maximum frequencies between the first and second notes. No significant correlation existed between the minimum and maximum frequencies within each note. This shows that only the minimum frequencies of the first and second notes are correlated and the maximum frequencies of the first and second note are also correlated. These correlations are partially due to the small frequency variation between notes and calls.

The minimum and maximum frequencies of both song replications per Burrowing Owl were lumped together and the 12 owls correlated with each other. This test demonstrated a significant positive correlation ($P < 0.05$) between all but four owls. It is of interest that three of these four owls that showed no significant correlation with the remainder of the population nested in a section of the area being destroyed by the Army Corps of Engineers. The flora also is sparser in this section and it does not appear to be as desirable a habitat. Thus although these owls' songs were adequate for pair formation, they may have been inadequate in territory defense in preferred habitat.

The durations of the first note, second note, and the interval between them were tested for correlations. A significant positive correlation ($P < 0.05$) was demonstrated between the first and second note and a significant negative correlation between the first note and the interval between the notes. Thus it appears that the duration of the entire song may be restricted to a certain time boundary. When the first note is lengthened, the second note is lengthened, and the interval between the notes is shortened, but it must be pointed out that the interval between the notes is still the least variable temporal component and it never fully compensates for the lengthening of the first and second note.

A correlation test was also performed between the 12 Burrowing Owls using data obtained by lumping the values for the duration of the first note, second note, and interval between the notes for both replicates, thus rendering one value per bird. This test indicated a significant positive correlation ($P < 0.05$) between all but one owl, a banded, first-year male and one of the three owls that nested in the less suitable portion of the arroyo. The song of this owl did not correlate with those of 7 of the remaining 11 owls of the population.

Discussion

Burrowing Owls give about 17 vocal displays. Of these, the adults give 13, the young 3, and both give 1. When the similarities between the calls are considered, it appears the owls may have only 9 basic calls, with variations on these producing the other 8.

Calls that appear to have no derivations and are not a derivation themselves are the tweeter, female defense warble, rattle, female copulation warble, snap, and possibly the juvenile eep.

The males' song during copulation and warble appear to be variations of the primary song. The chatter and scream given by the adults seem to be derived from the chuck call. The chatter appears to be formed by shortening and repeating the chuck call and the scream formed by lengthening it and broadening its frequency length. Apparently a relationship also may exist between the chatter and smack call. When compared closely (Figures 3C, 2A), the smack call appears to approximate the lower part of the down-slur of the chatter call. This may indeed be coincidence, but it may indicate the origin of the smack.

There may be a relationship between the juvenile eep call and the chuck call. The shortest eep call (Figure 4D) has the same characteristics as the chuck call, two up-slurs and a down-slur. What may take place is a decrease in the call's frequency, with the retention of its structure. It was noted in the laboratory that when young Burrowing Owls began giving the chuck and chatter calls, they no longer gave the eep call. The calls that they then gave agreed with the adult calls and were perfected without hearing adult vocalizations.

Young Burrowing Owls have a rasp call that appears identical to that of the adults, but young do not appear to have a vocalization approximating the female eep call. The female eep call grades into the rasp call (Figure 3D), but it is probably not a result of it. The rasp call, when given as a threat or when the owl is greatly distressed, is the vocalization considered to be a mimic of a rattlesnake. The rattlesnake rasp not only appears structurally similar to a rattlesnake rattling in that they are both wide frequency-length noises (Figure 5D), but both have their energies concentrated in much the same frequencies. The mean minimum and maximum frequencies at which the energies are concentrated for the juvenile rattlesnake call and rattlesnake rattles are 0.85–2.3, 3.1–5.7, and 4.7–6.6 kc/sec ($N = 4$) and 0.5–1.8, 3.0–4.4, and 4.9–6.4 kc/sec ($N = 3$). Thus there is good quantitative evidence demonstrating basic similarity in the sounds.

Juvenile feeding rasps have their energies concentrated at mean frequencies of 1.7–2.3, 3.6–4.9, and 5.5–6.0 kc/sec ($N = 6$). Structurally they also represent noise and are almost identical to the rasps given by females and juveniles when distressed or as a threat (Figure 5A, 5D). The difference between feeding rasps and distress-threat rasps is that the energies are concentrated about 0.5 kc/sec higher in the feeding rasps. Female feeding rasps are identical to their distress and threat rasps.

Some general rules that variance components of song appear to follow have been indicated by the analysis of passerine bird songs. The frequency components of song may have a greater variance than the temporal components (Marler and Isaac 1960, Falls 1963). Of the temporal components, the duration of notes may contain more variance than the duration between notes (Falls 1963). Frequency components of some birds may have little variation (Konishi 1964), but according to the above generalizations, the probability of conspecific recognition would be greater if the frequency, rather than the temporal pattern is varied.

Primary song in the Burrowing Owls also appears to follow these rules. Frequency varies more than the temporal components, and of the temporal components, the interval between notes contains the least amount of variance. This is significant in that it appears that the rules may not apply solely to passerines, but also to other groups of birds.

Certain Burrowing Owl calls closely resemble calls of birds in other orders and appear to have the same etiology and function. The eep call of juvenile Burrowing Owls functions as a distress and possibly hunger display. Collias (1963) demonstrated a call very similar to a Burrowing Owl eep as part of the repertoire of the African Village Weaverbird (*Textor cucullatus*). The call was given by young birds when hungry and/or distressed.

The rasp call of juvenile and adult Burrowing Owls also has some of the same structural components as the threat display of the African Village Weaverbird (Collias 1963). The rasp calls are also similar to the calls given by Long-billed Curlews (*Numenius americanus*) when distressed (Forsythe 1970).

The Burrowing Owl's chuck and chatter calls appear congruous with other bird vocalizations. The chuck and chatter calls are complex displays providing abundant location cues by phase, intensity, and time difference. This appears to be the call's function. When a Burrowing Owl is actively mobbing, it is to his advantage to attract other owls. When a Burrowing Owl displays to an approaching predator, the function is to cause the predator to follow him, thereby insuring the safety of the burrow. Forsythe (1970) reports that Long-billed Curlews also give a call similar in structure to the Burrowing Owl's chatter when mobbing. Thus many, if not all, of the Burrowing Owl vocalizations appear, as in other birds, to have been adapted to the function they perform.

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Summary

A breeding population of Burrowing Owls (*Speotyto cunicularia*) in Central New Mexico was studied during 1970 and 1971. Special emphasis was given to the owl's vocalizations. Burrowing Owls have a repertoire of at least 17 vocalizations. Adults give 13 calls, young 3, and both give 1. Primary song was given only by males and always when near their burrows. Similarities between calls indicate 8 of the Burrowing Owl's vocalizations may have evolved from a basic 9.

Analysis of variance of the components of primary song demonstrates that frequency components vary less than temporal components. The duration between notes varied less than other temporal components. The rattlesnake call of Burrowing Owls closely approximates the rattle generated by an agitated prairie rattlesnake (*Crotalus varidis*). Evidence suggests vocal mimicry may be involved for predator defense. Some Burrow-Owl vocal displays resemble displays of other groups of birds in their etiology and function. Burrowing Owl vocalizations apparently have been adapted to the function they perform.

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