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Structure and possible function of vocalizations of captive red-legged seriemas (Cariama cristata)

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To the Graduate Council:

I am submitting herewith a thesis written by Ami Elizabeth Padget entitled "Structure and possible function of vocalizations of captive red-legged seriemas (Cariama cristata)." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Psychology.

Todd M. Freeberg, Major Professor

We have read this thesis and recommend its acceptance:

Gordon M. Burghardt, Matthew A. Cooper

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Structure and possible function of vocalizations of captive red-legged seriemas (*Cariama cristata*)

A Thesis Presented for
the Master of Arts
Degree
The University of Tennessee, Knoxville

Ami Elizabeth Padget
May 2010

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Abstract

Very little is known about red-legged seriema (*Cariama cristata*) vocalizations and behavior. The focus of my research was to analyze the structure of red-legged seriema primary calls and to begin to test hypotheses related to their function. Captive red-legged seriema behavior, both vocal and non-vocal, was recorded at 7 institutions located in the United States from May 2007 through November 2008. To test whether calls serve a predator alarm function, seriemas were presented with a large stuffed dog, representing a predator stimulus, and 2 control stimuli, a large, stuffed penguin and a large, flowering potted plant. Baseline recordings with no manipulations were also made throughout the day, during the course of the study. All recordings of seriema vocalizations were assessed using sound analysis software to generate sound spectrograms for comparison. I identified three different note types within the seriema primary call: upsweep notes (U), ladder notes (L), and two-part notes (T). Each call begins with a set of U notes that increase in rate and lead into the main part of the call, which is made of L and T notes. Each note type was assessed for duration, frequency, energy, and entropy measurements. These measurements were reduced using factor analysis into two relevant factors. There were substantial differences across individuals for note type acoustic structure. Group differences in note types, including sex, location, and age, were not found. When presented with the dog model, vocal responses were given by only 3 individuals. Overall, it may be possible to identify individual seriemas by analyzing the structure of their primary call, which may allow researchers to identify individuals without physical markers.

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Chapter 1

Introduction

Overview

Vocalizations have been extensively studied in many songbird species (Catchpole & Slater, 2008). However, vocal behavior of many non-songbird species, including species with monolithic songs or calls (calls which are uniform and lack variety), has just begun to be studied in depth, and many species have not been studied at all. The research described here analyzed the structure of red-legged seriema (*Cariama cristata*) vocalizations and began to test hypotheses related to the function of their calls and duets. Specific aims of this project were to 1) record and analyze the calls of captive red-legged seriemas, 2) determine whether individual or group differences in calls exist, 3) investigate whether variation in call structure or production is associated with different contexts (territoriality or predator alarm), and 4) collect behavioral data to complete an ethogram and determine rates of behavior.

A census of population numbers for seriemas has never been conducted. The loud primary call of the seriema has led researchers to believe that red-legged seriema numbers in the wild may be overestimated and that seriema numbers in the wild are actually lower than predicted because they are often heard and not seen (Gonzaga, 1996). Studying the vocalizations of seriemas could allow passive monitoring of their population numbers in the wild, using acoustic parameter measurements to identify individuals. Past research has shown that by studying the vocalizations of bird species, including non-songbirds, it may be possible to distinguish between individuals or groups, which is important for identification in the wild (Budde, 1999b).

Researchers for decades have made it a priority to understand how and why animals communicate. What are the functions of the different signals that animals produce? In bird species, calls or songs given by individuals and the contexts in which they are produced are usually the focal point of study. Vocalizations most likely serve different functions in different contexts. Before the function, or functions, of a signal may be determined, it is necessary to determine the signal structure and the context in which it is used (Bradbury & Vehrencamp, 1998). Seriema vocal behavior may function to maintain pairs, as a predator alarm, or to aid in defense of territory, whether given by a single signaler or a pair of signalers. The present study began testing the function of the seriema vocalizations by analyzing their primary call structure and by exposing individuals to different contexts.

Seriema Background

Red-legged seriemas are one of the two members of the Family Cariamidae and are indigenous to South America. They are most closely related to the black-legged seriema (*Chunga burmeisteri*). Seriemas are currently placed as members of the Order Gruiformes, but this placement has been debated (Benirschke, 1977; Hallager, 2007a). They may be closely related to bustards (*Ardeotis kori*; Family Otididae), due to similar cestode parasites (Benirschke, 1977; Hallager, 2007a), or to kagus (*Rhynochetos jubatus*), who have similar behaviors and vocalizations, both of which are members of the Order Gruiformes (Gonzaga, 1996). It has also been suggested that seriemas are most closely related to the secretary bird (*Sagittarius serpentarius*), a member of the Order Falconiformes, due to the species' habit of hunting snakes (Schneider, 1957) and phenotypic similarities. However, this relationship was dismissed due to karyological differences, being that seriemas have 94 acrocentric only chromosomes and secretary birds have 90 mostly metacentric chromosomes (Benirschke, 1977). In 2008, new genetic evidence suggested that seriemas should be placed with the Falconiformes and are more closely related to raptors (Hackett et al., 2008). At this time, seriemas are still considered a suborder of the Gruiformes (Hallager, 2007a).

Red-legged seriemas range from eastern Brazil to eastern Bolivia and Paraguay, and into Uruguay and Argentina (Hallager, 2007a). Seriemas are seen most often in Central Brazil where they inhabit savannas covered in termite mounds, from where they frequently perch to call (Hallager, 2007b). Red-legged seriemas are omnivorous and flighted, but rarely fly. They can run at speeds of up to 25-40 kilometers per hour (Gonzaga, 1996). They are not considered a threatened species, but a formal census has never been completed and their numbers may be overestimated due to the long distance range of their call (Gonzaga, 1996). Actual wild population numbers are unknown.

The natural predators of this species are unknown at this time. It is assumed that medium to large canids or felids may be potential predators of adult seriemas (Gonzaga, 1996). Researchers have observed Geoffroy's cats (*Felis geoffroys*) carrying the carcasses of seriemas by the neck in northeastern Argentina (Yanosky & Mercolli, 1994). It is unknown whether or not Geoffrey's cats regularly feed on seriemas (Yanosky & Mercolli, 1994).

Seriema Vocalizations

The primary call of the red-legged seriema (Figure 1) is similar to the described calls of the black-legged seriema (Boyle, 1917), the Kagu, and wood rails (Rallidae) (Gonzaga, 1996). Their solo calls and duets have also been compared to the "yelping of a young dog" or the "cackling of turkey hens" (Burmeister, 1937). Red-legged seriema calls have been described as "a long, dramatic sequence of very loud yelping cries that form phrases, with a staggered variation in pitch" (Gonzaga, 1996). They are most often heard during the morning hours, but can be heard at any time during the day, as red-legged seriemas are a diurnal species. Their calls and duets are extremely loud and can be heard up to several kilometers away (Gonzaga, 1996).

Seriemas have one primary call, which consists of a series of different note types. These calls are differentiated from songs because they are relatively simple in acoustic structure, given by both sexes throughout the year, and usually occur in different contexts which relate to their function (Catchpole & Slater, 2008); thus the seriema vocalization seems to function more like the traditional view of a "call" compared to a "song". When two individuals call at the same time, it is considered a duet. Seriema calls usually begin with single notes, which increase in rate and lead into the climax of the call. Calls may last a few seconds or may continue for minutes. Occasionally, seriemas will produce single notes only. These notes do not always lead into the primary call. Schneider (1957) was the first researcher to attempt to analyze seriema calls. He divided the calls into three main parts, which he called preliminary-calls, main-calls, and after-calls. For the current analysis I elected to categorize the seriema call into different note types, instead of phrases. This allowed for easier and more objective analysis.

In a study that is foundational to my research, Redford and Peters (1986) analyzed the call structure of one captive individual and one wild individual, including a total of 4 call sequences. They found that red-legged seriema vocalizations consist of three phrases, each with a distinct composition. Phrase A consists of a series of short notes. Phrase B notes have the same structure as phrase A notes, but these short notes are now grouped into sub-phrases (such as pairs, triplets, or more). Phrase A and B would both be included in what Schneider (1957) referred to as preliminary-calls. Phrase C is the climax of the call and is the most structurally complex segment, consisting of 10 or more notes. Schneider (1957) referred to this part of the call as the main-call. These 3 phrases, A, B, and C, are not always produced together, as seriemas may stop at any time during the call (Redford & Peters, 1986).

Burmeister (1937) found that seriemas often call in unison, since they live in small groups (usually male/female pairs or pairs with offspring). He noted that when one seriema called, other seriemas in the area would answer back, as if counter-calling. Redford and Peters (1986) observed seriemas almost always perching on termite mounds, low trees, or fences when calling. They also found that seriemas often respond to the calls of other conspecifics by engaging in duets. This happened both within and between pairs (Redford & Peters, 1986). More recently, seriemas were observed aggressively attacking other conspecifics that entered the same area, and pairs were observed duetting and answering the calls of other conspecifics (De Almeida, 1994). De Almeida's study (1994) supports Redford and Peter's (1986) hypothesis that the call of the seriema functions in territoriality to separate family groups. Seriema duets meet Farabaugh's (1982) definition of a duet when both members of a pair participate with temporal coordination. They show all the common characteristics of a duetting species including exhibiting sexual monomorphism, being tropical species, holding year-round territories, and being monogamous (Farabaugh, 1982). These initial findings suggest calls and duets may function in long-range communication, including territory defense, and may provide information about individual and pair status.

Individual and Group Differences in Vocalizations

Individual vocal distinctiveness has been observed in many classes of animals, including amphibians (Bee, Kozich, Blackwell, & Gorhardt, 2001), birds (Lengagne, 2001), and mammals (Ceugniet & Izumi, 2004). Choosing the appropriate acoustic parameters to measure in each species is the key to being able to decipher between individuals or groups. Researchers have found that in male green frogs (*Rana clamitans*) fundamental frequency and dominant frequency of territorial calls can be used to identify individuals (Bee et al., 2001). Statistical analyses of the chick-a-dee call of tufted titmice (*Baeolophus bicolor*) have also shown potential for discriminating individuals using temporal, frequency (Hz), amplitude, and entropy measures (Owens & Freeberg, 2007). In eagle owls (*Bubo bubo*), a non-songbird with a long lifespan, duration of the territorial call can be used to discriminate individuals, and after two years, individuals can still be identified by calls (Lengagne, 2001). In Japanese monkeys (*Macaca fuscata*), duration and start and end frequencies of the coo call allowed researchers to discriminate individuals (Ceugniet & Izumi, 2004).

When studying cranes, a species closely related to seriemas, researchers have also found ways of analyzing vocalizations to identify individuals. In red-crowned cranes (*Grus japonensis*), duet structure has successfully been used to identify pairs, including duet starter (individual who initiated calling), ratio of maximum call frequencies, and frequency (Hz) of the male versus female call (Klenova, Volodin, & Volodin, 2008). Weekley (1985) found that fundamental frequency of calls for greater sandhill cranes (*Grus canadensis tabida*) was the best parameter for assessing voiceprint analysis (i.e. individual differences in calls). As a last example, the unison call of pairs of captive grey crowned cranes (*Balearica regulorum gibbericeps*) has reliably been used to identify individuals and pairs in the wild and in captivity using frequency (Hz) measures of different call types (Budde, 2001). This study was able to correctly identify between 75.8% and 95% of wild individuals and found a recording distance of 40 m to be sufficient to obtain good quality recordings.

Once it has been established that individuals can be identified by passive acoustic monitoring, a population census, or estimation of population density for a given area, may be possible. This technique has most commonly been used in cetacean studies to decipher area population densities. Off the coast of Hawaii fin whale (*Balaenoptera physalus*) vocalizations have been used to estimate local population size using underwater hydrophones to record calls (McDonald & Fox, 1999). Scientists have also successfully been able to estimate seasonal population densities of harbor porpoises (*Phocoena phocoena*) using passive acoustic monitoring of vocalizations paired with visual surveys (Berrow, O'Brien, O'Connor, & McGrath, 2009). Acoustic monitoring to estimate population size has also been shown to be possible in terrestrial species, such as African elephants (*Loxodonta africana cyclotis*) using an acoustic sensor array, giving a confidence interval of 95% (Thompson, Schwager, & Payne, 2010). This type of monitoring offers a lower cost, less invasive, and less time consuming option for assessing population status.

In addition, analysis of vocalizations may provide a way to detect group differences, including sex, age, or population. Analysis of the frequency (Hz) of guard call vocalizations of whooping cranes (*Grus americana*) provides a way to determine sex of individuals (Carlson & Trost, 1992). In addition, by analyzing temporal, amplitude, and frequency (Hz) measurements of the "Zzuss" call, an alarm call, of the primate silky sifakas (*Propithecus candidus*), researchers have been able to predict sex of individuals' (Patel, Anderson, & Owren, 2005). Age differences of individuals may also be detected using vocal analysis. In common marmosets (*Callithrix jacchus*), types of infant calls are completely different from types of adult calls on the basis of acoustic structure (Bezerra & Souto, 2008). Many species also exhibit differences in vocalizations across local populations. In golden-mantled ground squirrels (*Spermophilus lateralis* and *Spermophilus saturatus*), dialect and geographic variation in alarm call vocalizations of subspecies has been found (Eiler & Banack, 2004). Researchers have also found gargle vocalizations (an agonistic call) that are unique to local populations of black-capped chickadees (*Poecile atricapillus*) (Baker, Howard, & Sweet, 2000). Additionally, single note analysis, in contrast to whole call analysis, has been used to used identify local populations and sex of individuals in Carolina chickadees (*Poecile carolinensis*) using duration, frequency (Hz), and entropy measures (Freeberg, Lucas, & Clucas, 2003).

Function of Vocalizations in Different Contexts

Gruiformes species, the Order containing seriemas, often use vocalizations including individual calls, duets, and purrs in different contexts. For example, the Siberian crane (*Grus leucogeranus*) uses calls for aggression or threat, and as communication between mates and between parents and chicks (Bragina, 2006). All species of crane have calls that are used in predator alarm contexts and calls that are used in territorial contexts to respond to the approach of other conspecifics (Ellis, Swengel, Archibald, & Kepler, 1998). In Aldabra white-throated rails (*Dryolimnas cuvieri aldabranus*), call structure has been related to alarm, interspecific aggression, and sexual contexts (Huxley & Wilkinson, 1977).

As well as individual calling, many Gruiformes species participate in duets with conspecifics. There are many hypotheses about the function of duets. Duets are overlapping bouts of solo calling or singing that occur synchronously or antiphonally between mated pairs (Langmore, 1998). Duets are thought to have originated from joint territorial displays (Wickler, 1980). In duetting species, it is believed that this function is maintained while others are added (Wickler, 1980). For example, the magpie-lark (*Grallina cyanoleuca*) uses duetting in both defense of territory and as maintenance of the pair bond (Hall, 2000). Of the 15 species of cranes, all species participate in duets, also referred to as unison calls, with conspecifics (Archibald & Lewis, 1996). All crane species use duetting in pair formation and maintenance of the pair bond (Ellis et al., 1998). The greater sandhill crane uses duets in individual recognition between mates (Farabaugh, 1982). Siberian cranes often use duets as preparation for pair flight (Bragina, 2006).

In other non-songbird species, especially those species engaging in duets, it has been hypothesized that duets function to maintain the pair bond, to prevent being usurped from partnership, to prevent the partner from being usurped, and in territory defense (Hall, 2004). Most likely duetting has more than one function in most bird species (Hall, 2004). Red-legged seriema calls and duets would appear to fit Sonnenschein and Reyer's (1983) description of a territorial call function. According to their criteria, the call or duet must be high in volume, be given from a conspicuous site, be given year-round, and have a simple structure, with parts that can be given alone. By these criteria, seriema calls and duets would seem to function in defense of their territory, since seriemas are considered a territorial and sedentary species (Gonzaga, 1996; Redford & Shaw, 1989), but other possible functions are currently unknown.

Many Gruiformes species also emit a purring sound, simply called a purr vocalization (Ellis et al., 1998). A purr is a low frequency, quiet, short-range communication sound. Grey crowned cranes emit purrs when feeding, when preparing to fly, as a warning, prior to copulation, and while resting (Budde, 1999a). Most crane species also emit purrs when nest building, brooding, and feeding chicks (Ellis et al., 1998). The purrs of Aldabra white-throated rails (*Dryolimnas cuvieri aldabranus*) are actually a series of clicks and can be heard after duetting, at incubation changeover, and when meeting, allopreening, courting, feeding, preparing to copulate, nest building, and communicating with chicks (Huxley & Wilkinson, 1977). Greater sandhill cranes use purrs in interaction with individuals who are within a few meters (Weekley, 1985). Seriemas also emit a purring vocalization that can be heard during feeding, pair interaction, nest building, and when raptors fly overhead (personal observations).

Current Study

Red-legged seriema call notes have never been described quantitatively. The calls have simply been broken into phrases, usually three to four, for rudimentary analysis. I sought to perform in-depth analyses of the structure of seriema calls. Vocalizations from 15 captive individuals were recorded and analyzed to determine call structure and individual differences. For my analyses, calls were categorized into upsweep notes (U), which have an initial upsweep in frequency, ladder notes (L), which have a fairly consistent frequency, and two-part notes (T), which have a distinct frequency transition in the middle of each note (Figure 2). Each note was analyzed separately. These note types correspond roughly with Redford and Peters (1986) phrase definitions. Phrase A would be comprised of series of the current study's U notes, Phrase B would contain U notes and possibly L notes as the Phrase C was approached, and Phrase C would include a combination of T and L notes.

In the present study, 9 seriemas were also presented with 3 visual stimuli as a preliminary test to determine if vocalizations might be used as predator alarms. Seriema vocal and non-vocal behavior was recorded during each manipulation.

Non-vocal behavior was recorded throughout the study and included observations from 22 individuals. Detailed notes were taken on calling, perching, feeding, lying, walking, standing, preening, pecking, scratching, and stretching behavior. All descriptive data were collected to determine rates of common behavior and to compose an ethogram, which can serve as a quantitative tool for future research, allowing comparisons between closely related species (Litchenberg & Hallager, 2006). Ethograms offer a standardized way for similar studies to be conducted reliably (Bekoff & Webb, 1986).

Chapter 2

Methodology

Subjects and Institutions

This zoological study was conducted from May 2007 to November 2008 at seven institutions located in the United States including Knoxville Zoo (Knoxville, TN), Riverbanks Zoo (Columbia, SC), San Antonio Zoo (San Antonio, TX), Smithsonian National Zoological Park (Washington, DC), Sylvan Heights Waterfowl Park (Scotland Neck, NC), Wildlife World Zoo (Litchfield Park, AZ), and World Bird Sanctuary (Valley Park, MO). All recordings were made during the months of May through November. Winter months are too cold for seriemas to remain outdoors in North America and captive individuals are housed inside during these months. Recordings were not made during these winter months because the indoor environment did not allow for recording good quality vocalizations.

The study population consisted of 25 captive red-legged seriema individuals, including 12 males, 9 females, and 4 individuals of unknown sex (Table 1). During the study two chicks were born at Riverbanks Zoo and 2 chicks were born at the National Smithsonian Zoo. When chicks are born they remain with the parents for a period of a few months. Chicks were not included in this study because newly hatched chicks do not vocalize until they are a few weeks old (personal observation).

Data Collection

Vocal recordings were obtained from 20 individuals, but calls from only 15 individuals were used including nine males, four females, and two unknown individuals.

The final data set excluded five seriemas because of the lack of sufficient calling behavior or because recording quality was too poor. For this analysis, if individuals were duetting, each individual's call was analyzed separately and notes that overlapped another seriema's call were not analyzed.

Naturalistic observations were recorded for 22 individuals throughout the duration of the study. Observations from three individuals in the study were not made because of time constraints, though vocal recordings were made of these individuals. Each individual was identifiable by leg bands assigned by each institution, or by physical characteristics, such as coloring, limp, or size. All recordings specify individual calls and behavior. Non-vocal behavior was documented using hand-written notes and video recording equipment at the exhibit sites. Pictures using a digital camera were taken at each site and a detailed description of each enclosure was made.

Individuals that were housed together were recorded together and were never separated, as exhibit constraints did not make separating individuals possible. Recordings were made for a time of up to five hours per day per pair or individual. Calls were recorded between the hours of 0700 and 2000 local time. Baseline recordings included several ad libitum recording sessions of individuals or pairs. A period of adjustment for animals to become accustomed to researcher presence was not necessary, as all individuals were exhibited birds and were familiar with the presence of humans (Lehner, 1996). All recording equipment was located less than 1 meter outside of the exhibit, so as not to disturb naturalistic behavior. During naturalistic observation recording, several categories of common behavior were recorded by hand in a composition book, including calling, perching, feeding, lying, walking, standing, preening, pecking, scratching, and stretching. The time at which each of these behaviors occurred was also recorded.

A smaller subset of the study population was also exposed to visual stimuli, which consisted of the presentation of a predator stimulus (a large plush dog) and two controls (a large stuffed penguin and a large potted plant) (Figure 3). The dog was a life-size plush yellow lab, made by Melissa and Doug, LLC (Wilton, CT) and measured 36"x 11"x 24". The plush dog resembled what could be a potential natural predator for seriemas, a canine species. The penguin measured 20"x 7"x7" and was made by Toys R Us Animal Alley (Wayne, NJ). The plant used was a mixture of potted Begonias (*Begonia semperflorens*), varying in color. The average height of these plants was 12" and the pot used measured 18"x 12". Stimulus presentations were performed during late afternoons between 1400 and 1700 hours, when calling behavior occurs less frequently.

Of the original study sample, nine individuals were tested, including four males and five females. These nine individuals were housed as male/female pairs, except for one female. A baseline-stimulus-baseline (ABA) design was used to present each stimulus. Only one stimulus item was presented per day. The order in which each individual or pair received the stimuli was selected at random from six possible stimulus orders. Each stimulus presentation, dog model or control, began with a baseline-sampling period of 10 minutes, followed by the stimulus presentation for a time period of 10 minutes, which was then followed by another baseline sampling period of 10 minutes. During each stimulus presentation, vocal behavior and non-vocal behavior categories were recorded.

Vocal Recordings and Analyses

Recordings of red-legged seriema vocalizations were made using Sennheiser ME-62 and ME-66 microphones and an HHB MDP-500 Portadisc Portable MD Field Recorder. Calls and duets were recorded at a 44.1 kHz sampling rate at a 16-bit resolution and transferred from minidiscs to a computer for analysis using Cool Edit Pro 2.0 sound editing software. Analyses of calls were conducted using Avisoft SASLab Pro to generate sound spectrograms. Overlapping duets were not analyzed. A threshold setting of -20 db was used to standardize acoustic parameter measurements. Acoustic parameters measured from these spectrograms included duration (sec), root mean squared (volts), frequency of the fundamental (Hz), mean entropy (unitless), and bandwidth (Hz) of each call (Figure 4). Duration measures the amount of time from the beginning to the end of the note. Root mean squared is a waveform energy parameter derived from the entire note. Frequency of the fundamental measures the lowest frequency in a harmonic series. Entropy measures the amount of acoustic disorder/ randomness (i.e. noisiness) within a note. Bandwidth measures the width of the range in frequencies surpassing the threshold setting.

For analysis, each note was used to generate spectrograms to determine if individual or group differences exist. Only high quality notes were analyzed. Based on spectrograms each note was classified as either upsweep (U), ladder (L), or two-part (T) (Figure 2). Upsweep notes (U) are notes that typically occur alone or begin a call sequence and have an initial sweep in frequency. At the beginning of a call, U notes are given and often increase in rate as the climax of the call is reached. U notes are often given alone and are not always followed by L or T notes. Ladder notes (L) visually resemble a ladder, in spectrogram form, with little frequency modulation. These notes are not present in every call, but if present usually occur at the beginning and end of the climax of the call. Two-part notes (T) have a distinct frequency transition in the middle of the note. This break in frequency is visible near the onset of T notes and may be caused by the movement of the signaler's neck during the climax of the call. During this time seriemas position their beak skyward and move their neck up and down with the head almost touching their back. Using these definitions, an observer experienced in avian bioacoustic analysis independently scored notes types to test for reliability in classifying notes. Based on my coding of note types, I calculated percentage of agreement between observers.

Once each note was classified as U, L, or T, acoustic parameter measurements were taken for each note. Each note type was then tested for acoustic characteristics that may be helpful in discriminating between note types and individuals. This was accomplished by examining the potential for note type coding (PNTC) and the potential for individual coding (PIC), using the five parameters measured for each note type. Features that are less variable within note types than between note types, can potentially be used in note type discrimination (Bloomfield, Charrier, & Sturdy, 2004; Owens & Freeberg, 2007). The PNTC is the ratio of the coefficient of variation between note types (CV_b) and the mean of the coefficients of variation within note types (mean CV_w). PNTC values greater than 1 may potentially be useful in note type discrimination (Bloomfield et al., 2004). For birds to discriminate individual signals the variation of a parameter across individuals must be greater than the variation of a parameter within an individual (Bloomfield et al., 2004; Owens & Freeberg, 2007). The PIC was examined using the small samples formula (CV_b * 100)/ [CV_w * 100 (1+1/4*n*)] where for each note type examined separately, CV_b is the coefficient of variation between individuals, CV_w is coefficient of variation within an individual, and *n* is the number of cases analyzed for each individual. PIC values must be greater than 1 to be potentially useful for individual discrimination (Bloomfield et al., 2004).

The five parameters were then reduced with factor analysis (SPSS, Statistical Package for the Social Sciences, version 17.0), using the principle components method with varimax rotation. Factor scores were then used in analyses of variance (ANOVAs) to calculate individual, group, and note type differences. For cases of significant overall effects, Tukey's post hoc tests were used. U notes were collected from 13 seriemas, L notes were collected from 9 seriemas, and T notes were collected from 15 seriemas.

To test for group differences, individual mean factor scores for each note type were used (Table 2). Seriemas were grouped into three different categories including sex, location, and age. Individuals of unknown sex were not included in the analysis of sex differences. For location, individuals were grouped by institution including, Knoxville Zoo, San Antonio Zoo, Wildlife World Zoo, or Riverbanks Zoo. The other three institutions were excluded from this analysis because of insufficient calling behavior. For age, individuals were placed in three arbitrary age categories, 0-5, 5-15, or 16+ years old, designed to maximum sample size in each category. Individuals of unknown age were not included in the analysis of age differences.

Analyses to determine rates of common behavior were conducted for the naturalistic behavioral data collected. Of the original study population, 20 seriemas were included in these analyses. The data from the pair at the Smithsonian National

Zoological Park were excluded because the pair was nesting. Three other seriemas were excluded because time constraints prevented adequate data collection of behavior. Common behaviors for this study were defined as behaviors that were observed frequently during initial observations, occurred at a rate of more than 1% (based on results), and were mutually exclusive (Lehner, 1996). Zoo studies have indicated that even analyses of sporadic recordings of common behaviors give accurate results for overall rates of behavior (Margulis & Westus, 2008), which is why I choose to conduct rates of behavior analyses on only common behaviors. Each time a common behavior was observed it was recorded in a composition notebook under each individual seriema's data column.

For analyses, each individual's behavior was totaled for each focal sampling period. If a state behavior occurred during one minute it received a score of 1 for that minute. If an event behavior occurred one or many times within one minute, it received a score of 1 for that minute. The total for each behavior was then divided by the total number of minutes for that sampling period and converted into a percentage. Individual scores for each behavior were averaged across all sessions and totaled into am and pm rates of behavior (Figure 5). Overall, this may not be the ideal method for recording and analyzing behavioral data. However, it was not possible to video all sessions or to record behavior for both individuals simultaneously, given time and travel constraints. One-zero sampling measures may be problematic (Altmann, 1974), but in cases like preliminary studies, where many behavior categories must be recorded, this type of sampling can be very useful because it is a simpler than many other techniques. Studies have shown that one-zero scores provide a reliable index of the “amount” of behavior occurring, especially when the amount of time sampled is large (Diamond & Bond, 2004; Martin & Bateson, 1993).

Sampling periods that took place before 1230 were considered AM and those after 1230 were considered PM. Behaviors included in the analyses of common rates of behavior include perching, calling, feeding, lying, walking, pecking, preening, standing, stretching, and scratching. Any non-frequent or rare behavior was placed into an “other” category. The ethogram includes all observed behaviors, both common and rare (Table 3). Each behavior was placed into a category including locomotion, functional, resting/ stationary, maintenance, reproductive, or vocalizations. A measure of inter-observer reliability was conducted while observing a male/ female pair of seriemas to ensure observer accuracy in recording behavior.

Chapter 3

Results

The final analyses included a total of 2484 notes comprising 846 U notes, 538 L notes, and 1100 T notes. Reliability in classifying notes was high between 2 observers who classified 354 notes, averaging 91.8% agreement (98.9% for U notes, 79.7% for L notes, and 93.5% for T notes).

Factor analysis of the five parameters (duration, frequency, RMS, entropy, and bandwidth) generated two factors with eigenvalues >1 (Table 4). A parameter value greater than 0.6 determined which factor each parameter loaded onto. These two factors account for 76.5% of the total variation. Factor 1 represented primarily frequency and energy parameters, whereas Factor 2 represented primarily duration.

All three note types were significantly different from one another for Factor 1 (F(2,16) = 48.679, p < .001), but not for Factor 2 (F(2,16) = 2.366, p = .126; Figure 6). U notes have the lowest mean parameter values for Factor 1, ($\bar{x}$ = -0.768), L notes have intermediate values, ($\bar{x}$ = - 0.207), and T notes have the highest values, ($\bar{x}$ = 0.247). Thus, T notes typically have the highest fundamental frequency, bandwidth, RMS, and entropy, whereas U notes have the lowest of these measures.

PNTC analyses suggested that the acoustic parameters measured for each note type are, individually, limited in being able to discriminate note types. PNTC values for all measurements were very close to 1 (Table 5) with all values being within 0.2 of 1.

General Patterns of Calling

Out of 20 call sequences recorded from 7 pairs of individuals, duets occurred in

70% of these sequences. These duets limited my ability to analyze full calls or call sequences because non-overlapping calls are needed for analysis at the individual level.

Birds were perched 54.3% of the time when calling behavior was observed, using individual calling rate scores. However, this difference in calling when perched than when not perched is not significant (Wilcoxon signed-ranks test; $Z = -.070$, $p = .944$). In addition, four individuals had limited perches within their enclosure. If these individuals were excluded from the analysis, then the percent of time birds were observed perching when calling increases slightly to 63.6%.

Vocalizations were recorded during all months in which data collection took place, from May through November. In North America, seriema breeding takes place during all months, but the majority of eggs are hatched from April through July (approximately 72%) (Hallager, 2007a). From these data, it appears that seriemas vocalize during the breeding and non-breeding seasons, possibly year-round. In addition, calling behavior tended to be more frequent during AM hours than during PM hours. When comparing am calling behavior to pm calling behavior overall, the calling rate during the am hours was greater, 5.4%, than the calling rate during the pm hours, 4.9%.

Note ordering trends were also recognized. I randomly selected 10 calls within call sequences from 10 individuals and found that 100% of calls began with U notes. These U notes were followed by L notes in 50% of calls and by T notes in 50% of calls. The climax of each call included T notes 100% of the time. The T notes given during the climax were followed by L notes in 60% of calls and by T notes the remaining 40%. Calls ended with U notes 10%, L notes 50%, and T notes 40% of the time.

Individual Differences

U Notes. Factor analyses revealed significant individual differences in calling structure for both Factor 1 (F(12,845) = 35.973, $p < .001$; Figure 7a) and Factor 2 (F(12,845) = 11.519, $p < .001$; Figure 7b). Post hoc tests of differences show that four individuals for Factor 1 and four individuals for Factor 2 were very different from the remainder of the sample (Figure 7c). PIC analyses revealed that individual features of U notes alone cannot reliably be used to identify individuals. All PIC values were within 0.4 of 1 (Table 6).

L Notes. Significant individual differences were found for Factor 1 (F(8,537) = 13.625, $p < .001$; Figure 8a) and Factor 2 (F(8,537) = 107.666, $p<.001$; Figure 8b). Post hoc tests revealed that for Factor 1 three individuals and for Factor 2 seven individuals showed significant individual differences (Figure 8c). PIC analysis of L notes provided similar results to U notes. All values were very close 1 (Table 6).

T Notes. I detected strong individual differences for Factor 1 (F(14,1099) = 56.925, $p <.001$; Figure 9a) and Factor 2 (F(14,1099) = 35.129, $p < .001$; Figure 9b). For Factor 1 six individuals were very different and for Factor 2 four individuals were very different from other individuals (Figure 9c). T note individual features, when used alone, were also not a good indicator of individual identity, using PIC analysis. All PIC values were within 0.1 of 1 (Table 6).

Group Differences

U Notes. No significant effect of sex for Factor 1 (F(1,11) = .043, $p = .840$) or Factor 2 (F(1,11) = .386, $p = .548$) was detected. I detected no significant effect of location on U notes for Factor 1 (F(3,12) = .503, p = .690) or Factor 2 (F(3,12) = .042 , p = .988). Age also did not appear to have an effect on U notes using Factor 1 (F(2,11) = 1.604, p = .254) or Factor 2 (F(2,11) = .279, p = .763).

L Notes. No significant effect of sex for Factor 1 (F(1,8) = 1.631, p = .242) or Factor 2 (F(1,8) = .220, p = .653) was detected. Location appeared to have no effect on L notes for Factor 1 (F(3,8) = 1.225, p = .392) or Factor 2 (F(3,8) = 2.052 , p = .225). I detected no age effect on L notes for Factor 1 (F(2,8) = 1.761, p = .250) or Factor 2 (F(2,8) = 1.670, p = .265).

T Notes. No significant effect of sex for Factor 1 (F(1,12) = .240, p = .634) or Factor 2 (F(1,12) = .055, p = .819) was detected. No significant effect of location on T notes was detected for Factor 1 (F(3,14) = .893, p = .475) or Factor 2 (F(3,14) = 1.100 , p = .390). I detected no age effect on T notes for Factor 1 (F(2,12) = 1.504, p = .269) or Factor 2 (F(2,12) = .858, p = .453).

Stimulus Presentation

The dog model affected the behavior of eight of the nine seriemas presented with it. One older male gave no response. Sporadic flight, wing flapping, running, jumping to perch, and avoidance of the area in which the model was located were common behaviors observed when the dog model was present.

Vocal responses were obtained from three out of nine birds that received the dog model presentation, with two of these birds giving a primary call, which included upsweep notes. Neither control stimulus caused vocalizing, fleeing, nor stress behavior of any kind. The majority of seriemas approached the penguin control (8 of 9) and the plant control (7 of 9). The dog model was not approached by any seriema (0 of 9). Analyses showed an overall effect of approach (Cochran's Q test; Q = 12.667, p = .001). Pairwise comparison using sign tests were significant showing that birds avoided the dog model, while approaching the penguin (p = .008) and plant (p = .016).

Naturalistic Behavior

Calculating behavior rates revealed the amount of time this population of captive seriemas spent performing common behaviors. Over 100 hours of naturalistic behavioral observation were recorded throughout the duration of the study. Behaviors recorded during the AM hours (0700 to 1230 local time) include perching (8.0%), calling (5.4%), feeding (10.8%), walking (18.3%), lying (3.1%), pecking (11.8%), preening (12.2%), standing (13.3%), stretching (0.9%), and scratching (1.7%). Individual behavior rates are listed in Table 7. These behaviors accounted for 85.5% of behavior during the AM hours. The other 14.5% of the time was spent performing non-frequent or rare behaviors. Behavior rates for common behaviors were also calculated for the PM hours (1231 to 2000 local time) and include perching (4.7%), calling (4.9%), feeding (9.9%), walking (19.8%), lying (3.4%), pecking (11.9%), preening (11.8%), standing (16.3%), stretching (2.0%), and scratching (1.8%). These behaviors accounted for 86.5% of behavior during the PM hours. Behaviors considered to be rare for the purpose of this study were also recorded. Examples of some of these behaviors include sunning or dust bathing, which was observed 21 times, fluff and ruffling behavior, observed 27 times, and drinking, observed 5 times overall.

Two independent observers recorded the behavior of a male/ female pair. Cohen's

Kappa statistics showed high inter-observer agreement for most behavior categories recorded, including calling (K = 1.000), eating (K = 0.831), drinking (K = 1.000), lying (K = 1.000), interacting with chicks (K = 0.804), preening (K = 0.852), pecking (K = 0.737), walking (K = 0.854), stretching (K = 0.807), running (K = 0.744), jumping (K = 0.883), fluff and ruffle (K = 1.000), scratching (K = 1.000), and whacking (K = 1.000). Some rare behaviors were included in the analysis. Drinking was not observed during the sampling period and scratching, fluff and ruffle, and whacking were only observed once. Standing (K = 0.604) was the only behavior that did not show high inter-observer agreement.

Chapter 4

Conclusions and Recommendations

The present study analyzed the vocalizations and common non-vocal behavior of red-legged seriemas. Spectrograms were used to classify notes into categories to determine if individual or group discrimination was possible. It was found that it is possible to identify individual seriemas by measuring acoustic parameters of their primary calls. However, based on the results of the sample in this study, it appears that sex, age, or location do not have substantial effects on call structure in this species.

Vocalizations

Seriema vocalizations were classified into three distinct note types, upsweep notes (U), ladder notes (L), and two-part notes (T). Factor analysis reduced my five measured parameters to two main factors. These two factors revealed strong individual differences. Factor 1 also exhibited strong note type differences. Factor analysis indicated that each note could potentially be useful for individual discrimination in field studies of wild seriemas. The current study found that by measuring acoustic features of seriema calls, individual differences were large. This is potentially an important finding for future conservation efforts. Passive acoustic monitoring to determine numbers of individuals in the wild, offers a low-budget, easy alternative to current monitoring methods such as radio tagging, ringing, and karyotypic analysis (Budde, 2001). Seriema numbers in the wild are currently unknown. If field researchers are able to record medium to high quality seriema calls, it may be possible to count individual birds. This could allow for the potential to identify more birds, using fewer resources, such as time and money, all the while minimizing potential stress to or disturbances of seriemas being monitored.

Note types categorized here were acoustically distinct from one another. For Factor 1, a hierarchy is present between these note types, with U notes having lower values for the five acoustic parameters measured, L notes having intermediate values, and T notes having the highest values (Figure 6). This finding makes sense given the placement of note types within the seriema call as seen in the results. U notes always occur at the beginning or on occasion at the very end of a call and have the lowest intensity. L notes usually occur directly before or after T notes. T notes typically occur at the climax of the call and are the loudest notes in the call. The rising and falling sound of the seriema call has been described by Schneider (1957) as a call in which "sounds gain a higher pitch" and get stronger as the call proceeds and speeds up. This is followed by, after the climax of the call, a "fall in the heighth and strength of the tone" (Schneider, 1957). The current study of acoustic parameters confirms this description.

Group differences in these vocalizations were not found during this study. No effects of sex, age, or institution location were detected for the acoustic features of U, L, or T notes. This lack of any detectable group differences may suggest that these calls are not the result of social learning, as is often seen in a different type of vocal signal, songs. Calls are shorter and simpler than songs and occur in certain contexts that can relate to a specific function (Catchpole & Slater, 2008). Group differences in songs are usually apparent, especially sex differences, such as in many songbirds in which male songs greatly differ from that of the females. Further research is needed to determine the origin of the seriema primary call and a comparative field study is needed to determine if group differences exist in the wild. Group differences may not be apparent in captive individuals. These individuals are transferred to new locations, sometimes frequently, throughout their lives, and are often paired with different individuals (Hallager, 2007a).

Possible Functions of Vocalizations

From the manipulation stage of the study, seriemas appeared to perceive the stuffed dog as a potential threat and results are consistent with a predator response. However, for this manipulation I used a single, plush, non-moving stimulus, which is not as threatening as a moving predator. This did not appear to affect the seriemas initial response, but in the future I recommend that a moving predator be employed, as well as predators of different sizes and colors. Practical constraints did not allow for a thorough study of this type. In addition, future research is needed to determine what features of this and other predator models are seen as a threat. Furthermore, since I only used one variant of each stimulus type, the test of a predator function here was pseudoreplicated. Future studies should utilize multiple variants of each stimulus type.

Changes in vocal behavior when the dog model was presented were not consistently detected. The primary call, including upsweep notes, was recorded from two individuals, and one bird produced only upsweep notes when the dog model was present. Six birds did not call at all when the dog model was presented. Alarm calling is common throughout the animal world (Naguib, Clayton, Zuberbühler, & Janik, 2009). However, the inconsistent manner with which the seriemas used their call when the dog model was presented did not give strong evidence that it is used in alarm contexts.

The primary call of the seriema has been thought to act in defense of their territory; however, this has never been formally researched (Hallager, 2007a). The results of the current study cannot rule out this territorial function hypothesis. Seriema calls subjectively meet the criteria for a territory defense function. The criteria for territorial calls states that calls must be high in volume, given from conspicuous sites, given year round, and have a simple structure, with parts that can be given alone (Sonnenschein & Reyer, 1983). My results indicate that seriema calls are high in amplitude, are given from a conspicuous site 63.3% of the time, are given during breeding and non-breeding season months, and do have a simple structure, consisting of 3 note types.

Another possible function for seriema calls is pair bond maintenance. The current study was not designed to test this function. However, if calls did function in this capacity then birds that were housed individually without a mate should not have participated in calling. Individually housed birds (N=3; Tables 1 and 2) did vocalize throughout the duration of this study, which would not support pair bond maintenance as the primary function of the seriema call.

Seriemas were observed perching on an object, including logs, their nest, trees, rocks, and the edge of food or water bowls approximately 63.3% of the time when solo calling or duetting. Past observations of seriema calling behavior had also indicated a trend towards perching when calling (Schneider, 1957; Redford & Peters, 1986). It was expected that seriemas would perch a majority of the time when vocalizing because red-legged seriema calls and duets appear to fit in with Sonnenschein and Reyer's (1983) description of a territorial call function, which includes calls being given from a conspicuous site. Other research has found that many territorial non-songbird species call louder than needed for within group communication, call from prominent places, and counter-duet with nearby conspecifics (Hall, 2000). Seriema vocalizations and behavior do fit these descriptions.

Naturalistic Behavior

From the naturalistic behavioral data recorded throughout the duration of the study, it was possible to calculate rates of common behaviors and to develop an ethogram of 47 red-legged seriema behaviors and vocalizations. There are no detailed descriptions of seriema behavior that have been published to date. The current study offers a foundation on which to begin future quantitative studies of seriema or closely related species' behavior.

Based on this analysis, captive seriemas spent a majority of their time perching, calling, feeding, walking, lying, pecking at different substances, preening, standing, scratching, or stretching. Time-of-day differences for non-vocal behaviors were not found. These behaviors represent only four categories of behavior, including locomotion, functional, resting/stationary, and maintenance, and are only 9 of the 47 behaviors observed and included in the ethogram. Some commonly observed behaviors, which occurred with high frequency, may be the result of captivity and may occur at lower frequencies in wild individuals. Also, in captivity, nonplastic behaviors (e.g. feeding and locomotion) may be observed frequently, while plastic behaviors (e.g. copulation and play) may not, perhaps due to limited space. Human disturbance may also contribute to observed rates of behavior, which may potentially add an element of stress and inhibit natural behavior (Liu et al., 2009).

Ethograms are needed to standardize the way in which behavioral observations are reported, so comparative studies will be reliable (Bekoff & Wells, 1986). I adapted the ethogram terminology for this study from a recent ethogram from a closely related species, kori bustards (Lichtenberg & Hallager, 2006). I was able to assemble an ethogram of six categories, including locomotion, functional, resting/stationary, maintenance, reproductive, and vocalizations. Since the current study only included behaviors of captive individuals, it is possible that other behaviors exist that only occur in wild individuals, but are not included in this ethogram.

As discussed earlier, phylogenetic placement of seriemas is currently debated. Based on the current study, structure of seriema calls suggest a relationship to other crane species, the Order Gruiformes, in which seriemas are currently placed. Spectrographic analyses reveals that note types of seriemas and cranes are acoustically similar (for example, see Budde, 1999; Budde, 2001). Crane notes often have an initial frequency upsweep similar to that seen in seriema notes. Secretary birds, of the Order Falconiformes, which are phenotypically similar to seriemas, are almost always silent (Ferguson-Lees & Christie, 2001). In conclusion, based on calling behavior and call structure my behavioral data suggests seriemas should remain with the Order Gruiformes.

Recommendations

Rare behaviors may have approached common frequencies had enrichment items been provided. On sunny days, I occasionally observed seriemas sunning or dust bathing. Throughout the duration of the study, as seen in my results, I observed sunning behavior 15 times and dust bathing 6 times. It is possible that these behaviors may have been more common if all seriema exhibits provided an open area to permit direct sunlight or an area of dirt or sand for seriemas to use to dust bathe. Of the seven institutions where data were collected, four had sand or dirt areas available, while three had no appropriate areas available. All birds at the institutions with appropriate areas preformed sun and dust bathing, while birds at institutions with no areas available did not. The older pair at the San Antonio Zoo had no areas available the first year of data collection and did not sun or dust bathe. However, during the second year of data collection appropriate substrate was available and these seriemas did participate in sun and dust bathing behaviors. Zoos should take care to make appropriate substrates available, such as fine dirt or sand to promote this naturalistic behavior. Observing rare behaviors provides a unique opportunity to enhance current enrichment techniques. When rare behaviors are observed, enrichment opportunities should be developed to promote these naturalistic behaviors.

The overall “calling while perched” rate may have been affected by the exhibit design or set-up. Some exhibit ceilings were very low or lacked appropriate perching material, making perching behavior difficult (personal observation). Out of the seven institutions visited, five had appropriate perches and high ceilings, including Knoxville Zoo, Riverbanks Zoo, Smithsonian National Zoological Park, Wildlife World Zoo, and San Antonio Zoo. Sylvan Heights Waterfowl, which had a low ceiling, and Worldbird Sanctuary, which had a high ceiling, both had limited perches, although both did have elevated nests. Perching behavior when calling occurred at four locations with appropriate perches. The Smithsonian National Zoological Park had appropriate perches and ceiling height, but had nesting seriemas, which did not call. I recorded no primary calls from the two locations with limited perches. Captive red-legged seriemas should have appropriate perches throughout their exhibits and, based on my findings, I would recommend that exhibit ceilings be greater than 3 meters high to promote natural calling behavior of this species.

Zoos and other animal institutions, such as sanctuaries or breeding facilities, provide a wonderful place for comparison studies of a species. Much behavioral research needs to answer questions that cannot be solved in the field alone. Zoos can work as a supplement to these studies to answer questions that may not be answered otherwise (Budde, 2001). Recording vocalizations and non-vocal behavior in the field can be challenging and difficult. Zoos provide a wonderful opportunity to begin study of a species with relative ease, allowing for good quality recordings of vocalizations and behavior.

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Appendix

Table 1. Seriema Individual Information

Stud #	Individual	Sex	Location	Study Information Obtained	Housing
256	Male 2	M	Knoxville Zoo	Descriptive, Calls	Paired with 257
257	Male 1	M	Knoxville Zoo	Descriptive, Calls	Paired with 256
95	Breeder Male	M	Knoxville Zoo	Descriptive, Calls Manipulation	Paired with 164
164	Breeder Female	F	Knoxville Zoo	Descriptive, Calls, Manipulation	Paired with 95
205	Birdshow	F	Knoxville Zoo	Calls, Manipulation	Alone
52	Old Male	M	San Antonio Zoo	Descriptive, Calls, Manipulation	Paired with 49
49	Old Female	F	San Antonio Zoo	Descriptive, Calls, Manipulation	Paired with 52
271	Young Male	M	San Antonio Zoo	Calls, Manipulation	Paired with 272
272	Young Female	F	San Antonio Zoo	Manipulation	Paired with 271
250	Breeder Male	M	Sylvan Heights	Descriptive, Dog only	Paired with 191
191	Breeder Female	F	Sylvan Heights	Descriptive, Dog only	Paired with 250
176	Breeder Male	M	Smithsonian National Zoological Park	Descriptive (Nesting)	Paired with 178 and chicks
178	Breeder Female	F	Smithsonian National Zoological Park	Descriptive (Nesting)	Paired with 176 and chicks
174	Breeder Male	M	Riverbanks Zoo	Descriptive, Calls	Paired with 120 and chicks
120	Breeder Female	F	Riverbanks Zoo	Descriptive, Calls	Paired with 174 and chicks
206	Front Male Education	M	Wildlife World Zoo	Descriptive, Calls	Alone
261	Back Male Education	M	Wildlife World Zoo	Descriptive, Calls	Alone
64	Breeder Male	M	Wildlife World Zoo	Descriptive, Calls	Paired with 242
242	Breeder Female	F	Wildlife World Zoo	Descriptive	Paired with 64
4	Lory Bird 1	UNK	Wildlife World Zoo	Descriptive	Paired
5	Lory Bird 2	UNK	Wildlife World Zoo	Descriptive	Paired
2	Monk Bird 1	UNK	Wildlife World Zoo	Descriptive, Calls	Paired
3	Monk Bird 2	UNK	Wildlife World Zoo	Descriptive, Calls	Paired
155	Breeder Male	M	World Bird Sanctuary	Descriptive Manipulation	Paired with 156
156	Breeder Female	F	World Bird Sanctuary	Descriptive, Manipulation	Paired with 155

Table 2. Individual Mean Scores for Parameters

Mean factor scores for each individual seriema were used to calculate group differences for each note type including (a) upsweep notes (U), (b) ladder notes (L), and (c) two-part notes (T).

(a) Upsweep

Individual	Duration	RMS	Frequency	Bandwidth	Entropy
3	0.11643	0.03887	1316.61	2084.68	0.27196
49	0.12832	0.03963	1454.17	2018.98	0.23557
52	0.11672	0.05266	1365.93	2682.21	0.26923
64	0.14150	0.04439	1454.13	3124.13	0.27997
95	0.12049	0.05601	1021.33	3489.73	0.32431
120	0.11292	0.02693	1358.63	1887.29	0.24988
164	0.11608	0.09737	1039.49	1958.53	0.24908
174	0.13911	0.05562	1336.29	2423.32	0.25629
205	0.13233	0.29001	1527.60	5693.73	0.43737
206	0.10903	0.18992	1506.15	4177.74	0.34439
257	0.14052	0.10494	1290.96	2986.64	0.29764
261	0.12865	0.18496	1283.37	4062.28	0.34072
271	0.11966	0.06501	1806.45	3744.50	0.33145

(b) Ladder

Individual	Duration	RMS	Frequency	Bandwidth	Entropy
49	0.11020	0.06488	1489.20	2687.00	.23800
52	0.12925	0.08990	1695.27	4783.48	.34885
95	0.05805	0.06126	1408.94	4747.82	.38813
120	0.09829	0.04663	1365.57	3493.43	.31786
164	0.10067	0.10207	1352.33	3071.67	.32400
205	0.11223	0.30513	1562.70	5875.83	.42347
206	0.10823	0.19554	1698.00	4861.58	.38015
261	0.13522	0.26874	1484.71	6134.23	.38764
271	0.13258	0.08764	1993.33	3896.25	.34167

Table 2. Continued

(c) Two-Part

Individual	Duration	RMS	Frequency	Bandwidth	Entropy
2	.11227	.10865	1745.55	6567.27	.41500
3	.09518	.08897	1873.80	5927.65	.41957
49	.11879	.08808	1580.21	4594.39	.35257
52	.11855	.08478	1830.08	6042.43	.43033
64	.12396	.10970	1540.00	4512.68	.37079
95	.05429	.12970	1613.18	6273.11	.45600
120	.10400	.06418	1726.95	3565.15	.31690
164	.09444	.16948	1423.67	4343.67	.36136
174	.12706	.19153	1545.00	6196.67	.41994
205	.11921	.35908	1888.37	7973.79	.49891
206	.10235	.23060	1755.44	5898.94	.40710
256	.11738	.13146	1448.81	5514.25	.40981
257	.11798	.14691	1819.85	6473.04	.40298
261	.12614	.24920	1776.09	7214.02	.42469
271	.12284	.09997	2108.37	3783.84	.33732

Table 3. Ethogram

A red-legged seriema ethogram was developed from naturalistic behavior observations of 22 captive seriemas. Ethogram behaviors have been grouped into 6 categories, including locomotion, functional, resting/ stationary, maintenance, reproductive, and vocalizations and include a description of 47 basic behaviors and vocalizations. Each behavior has been defined as either a state (S) or event (E).

Locomotion
Walking (S)
Alternating movement of legs at a steady rate.
Running (S)
Alternating movement of legs at a rapid rate.
Flying (S)
Extension of wings, with flapping, with no body part touching substrate.
Jumping (E)
Legs are bent, then extended, and both feet leave the ground simultaneously without wing flapping.
Chasing (S)
Running while directing body toward an animate object.
Hock Walking (S)
Bird has tarsi on the ground and the tibias are vertical, with belly not touching the ground and from this position moves forward using legs.

Table 3. Continued

Pacing (S)
Walking back and forth repeatedly along the same track.
Kicking (E)
Jump and thrust both legs forward.
Startle (E)
Tensing of the body followed by a jump and/or wing flapping.
Functional
Prey Capture (E)
Chasing flying or crawling insects or small vertebrates and detaining them with beak.
Feeding (S)
Pecking, using beak, to consume foliage or may repeatedly drop and shake pieces of food over and over, followed by tearing food, while using beak to tear and feet to hold and then consuming by tilting head back to swallow food.
Digging for Prey (E)
Using beak to burrow into substrate to find and obtain prey.
Allofeeding (E)
Adults bring food to each other and pass and forth between beaks several times before being consumed.

Table 3. Continued

Whack Food or Objects (E)
Throwing food or inanimate objects on ground repeatedly using beak to hold and neck to thrust.
Object Pass (E)
Delivering inanimate items back and forth between individuals using beaks.
Drinking (S)
Consuming water, while standing, using a repeated scooping motion with beak with head tilted back to swallow.
Foraging (S)
Scanning the ground for food while walking.
Pecking (S/E)
Using beak to investigate substrate, enclosure, another bird, plants, prey, or other objects.
Bill Wiping (E)
Individuals rub the sides of their beak on the ground or other objects.
Defecation (E)
Excreting feces from a standing position with tail feathers raised away from the cloaca.
Looking (S/E)
Attenuate head and eyes toward observer or a moving object located outside enclosure.

Table 3. Continued

Skyward Looking (S/E)
Extending neck and using one or both eyes to look upwards. If using only one eye, the head is tilted.
Listening (S/E)
Attenuate head and extend neck in the direction of a sound.
Resting/ Stationary
Standing Perch (S)
Body is positioned in a stationary stance unipedally or bipedally on an elevated object.
Lying Perch (S)
Body is positioned in a lying position on an elevated object.
Hock Sitting (S)
Sitting position, in which the bird has tarsi on the ground and the tibias are vertical, with belly not touching the ground.
Lying (S)
Legs folded and tucked under body with belly touching the ground.
Head Tuck (S)
Standing with the head tucked against the back of the neck with body feathers fluffed.

Table 3. Continued

Maintenance
Scratching (E)
Using the talons on the feet to rub a body area.
Stretching (E)
Leg and wing on the same aide of the body are extended backward at the simultaneously and may include the upward extension of wings.
Body Fluffing (E)
Feathers on the body, neck, and wings are erected for a few seconds.
Ruffling (E)
Shaking the body in a wavelike manner, from head to tail.
Preening (S)
Grooming feathers using beak to peck, pull, and clean feathers, with or without the use of the preening gland, which is located at the base of the tail.
Dust Bathing (S)
Lying on substrate, usually dirt or sand, to rubs body, wings, head, and neck on ground and may also roll onto the side of the body.
Sun Bathing Lying (S)
Lying on belly in direct sunlight with wings extended and spread on the ground, while lying very still.

Table 3. Continued

Sun Bathing Standing (S)
Standing in direct sunlight with wings dropped to the sides to expose the back of the body.
Bill Gaping (E)
Beak is opened wide and then shut.
Bill Open (E)
The beak is held partially open while standing or walking.
Coughing/ Sneezing (E)
Air is expelled from the lungs noisily and suddenly, voluntarily or involuntarily.
Choke (E)
Beak is opened wide and held opened while extending neck forward. Debris may or may not be expelled.
Reproductive
Copulation (S/E)
Male climbs onto the back of the standing female to allow transfer of sperm.
Nest Building (S/E)
Collecting of leaves and sticks by a male/ female pair and consolidating them in a bush or tree.
Incubation (S)
Male and female parents alternate positioning their bodies over the nest, in a lying or standing position.

Table 3. Continued

Vocalizations
Purr (S/E)
Very quiet, low frequency, short-range sound (Figure 1).
Single note (E)
Short, loud, vocalization that consists of a "whooop" sound. Current study refers to this as a U note (Figure 2).
Primary call (S/E)
Loud vocalization given from a stationary, standing position that begins with U notes and increases in intensity and structure through the climax, involving L and T notes (Figure 1). The beak is pointed upward, while the head and neck move up and down. Head may touch the back of the body.
Hiss (E)
Short-range vocalization directed at non-threatening intruders or nuisances.

Table 4. Factor Loadings

Factor loading and variance explained by the 5 acoustic parameters.

Parameter	Factor 1	Factor 2
RMS	.803	.025
Frequency	.672	.205
Bandwidth	.926	.000
Entropy	.920	-.063
Duration	.037	.987
Eigenvalue	2.804	1.020
Variance explained	56.071	20.409
Cumulative variance	56.071	76.481

Table 5. Potential for Note-Type Coding (PNTC)

The PNTC is given for each acoustic parameter measured with the ratio of the coefficient of variation between note types (CV_b) and the mean of the coefficients of variation within note types (mean CV_w).

Measurement	CV_b	Mean CV_w	PNTC
Duration	22.3	22.4	1.0
RMS	79.1	80.9	1.0
Frequency	22.5	19.4	1.2
Bandwidth	52.7	48.0	1.1
Entropy	28.1	23.8	1.2

Table 6. Potential for Individual Coding (PIC)

The PIC is given for each acoustic parameter measured with CV_b, the coefficient of variation between individuals and mean CV_w, the coefficient of variation within an individual.

	Duration	RMS	Frequency	Bandwidth	Entropy
Upsweep					
CV_b	20.4	94.4	20.1	70.4	31.5
Mean CV_w	18.5	65.4	15.0	59.5	23.1
PIC	1.1	1.4	1.3	1.2	1.4
Ladder					
CV_b	25.4	93.3	19.1	39.3	20.9
Mean CV_w	18.3	57.2	20.1	46.7	18.7
PIC	1.4	1.6	1.0	0.8	1.1
Two-Part					
CV_b	21.5	54.9	19.2	34.2	19.0
Mean CV_w	21.0	55.6	18.3	33.5	17.0
PIC	1.0	1.0	1.1	1.0	1.1

Table 7. Individual Rates of Behavior

Common rates of behavior are given for each individual seriema for a) AM hours and b) PM hours.

(a) AM

	Individual																	
	2	3	49	52	64	95	120	155	156	164	174	191	206	242	250	256	257	261
Calling	0.0	0.0	14.0	19.0	0.0	0.0	11.0	0.0	0.0	17.6	10.2	0.0	3.8	0.0	0.0	0.0	0.0	20.8
Perching	0.0	2.6	0.0	7.2	0.0	8.8	13.0	2.2	13.5	0.0	30.2	0.4	7.7	0.0	11.6	0.0	0.0	45.8
Feeding	28.6	26.3	5.8	8.0	0.0	8.8	5.7	15.3	10.8	5.9	11.8	6.8	0.0	29.7	6.3	8.7	15.0	0.0
Lying	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	0.0	0.0	0.0	5.4	0.0	0.0	7.9	4.3	20.0	0.0
Walking	4.8	0.0	16.6	18.7	71.0	14.7	29.5	15.9	1.7	14.7	18.4	45.2	0.0	21.6	18.2	8.7	25.0	4.2
Pecking	14.3	36.8	7.0	6.2	3.2	2.9	16.8	4.3	4.1	11.8	4.5	14.9	0.0	13.5	9.6	52.2	10.0	0.0
Preening	4.8	13.2	21.1	2.8	9.7	26.5	0.0	20.0	16.7	0.0	7.6	7.7	53.8	5.4	7.2	0.0	15.0	8.3
Standing	23.8	5.3	25.6	6.1	6.5	26.5	13.2	0.0	33.5	38.2	1.5	4.6	0.0	18.9	19.7	4.3	0.0	12.5
Scratching	0.0	0.0	1.1	1.8	0.0	0.0	0.0	2.2	3.0	0.0	1.5	2.2	3.8	2.7	2.7	4.3	5.0	0.0
Stretching	0.0	0.0	2.2	0.7	0.0	0.0	0.8	2.5	3.3	0.0	1.5	0.4	3.8	0.0	0.7	0.0	0.0	0.0
Other	23.8	15.8	6.6	7.2	9.7	11.8	9.9	20.2	13.4	11.8	12.9	12.3	26.9	8.1	16.0	17.4	10.0	8.3

Table 7. Continued

(b) PM

	Individual													
	4	5	49	52	64	95	120	164	174	191	242	250	256	257
Calling	0.0	0.0	9.0	5.0	31.6	0.0	2.4	0.0	2.2	1.1	4.5	11.8	0.0	0.0
Perching	0.0	44.4	12.4	2.7	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0
Feeding	32.0	22.2	10.5	10.0	0.0	1.0	4.3	2.5	16.4	3.1	22.7	8.1	4.4	1.1
Lying	0.0	0.0	2.5	0.0	0.0	0.0	2.0	0.0	3.8	0.0	0.0	1.8	22.7	14.7
Walking	28.0	14.8	19.5	16.5	5.3	11.2	45.0	12.9	5.6	77.7	0.0	32.4	1.6	6.5
Pecking	12.0	7.4	8.1	17.3	5.3	7.5	12.5	4.2	26.6	6.7	13.6	9.4	19.4	16.7
Preening	4.0	0.0	7.3	1.0	5.3	25.6	4.0	33.8	5.6	1.9	4.5	7.2	25.8	39.2
Standing	12.0	0.0	13.3	5.8	36.8	33.5	10.7	28.9	12.7	2.9	36.4	19.1	7.1	8.2
Scratching	0.0	0.0	1.3	1.7	0.0	5.8	0.6	1.3	0.0	0.8	0.0	0.6	7.8	4.3
Stretching	8.0	0.0	2.9	1.0	5.3	2.0	0.0	3.7	3.9	0.0	0.0	0.4	0.0	0.0
Other	4.0	11.1	13.1	14.0	10.5	13.5	18.5	12.9	18.2	6.2	18.2	9.2	6.5	8.2

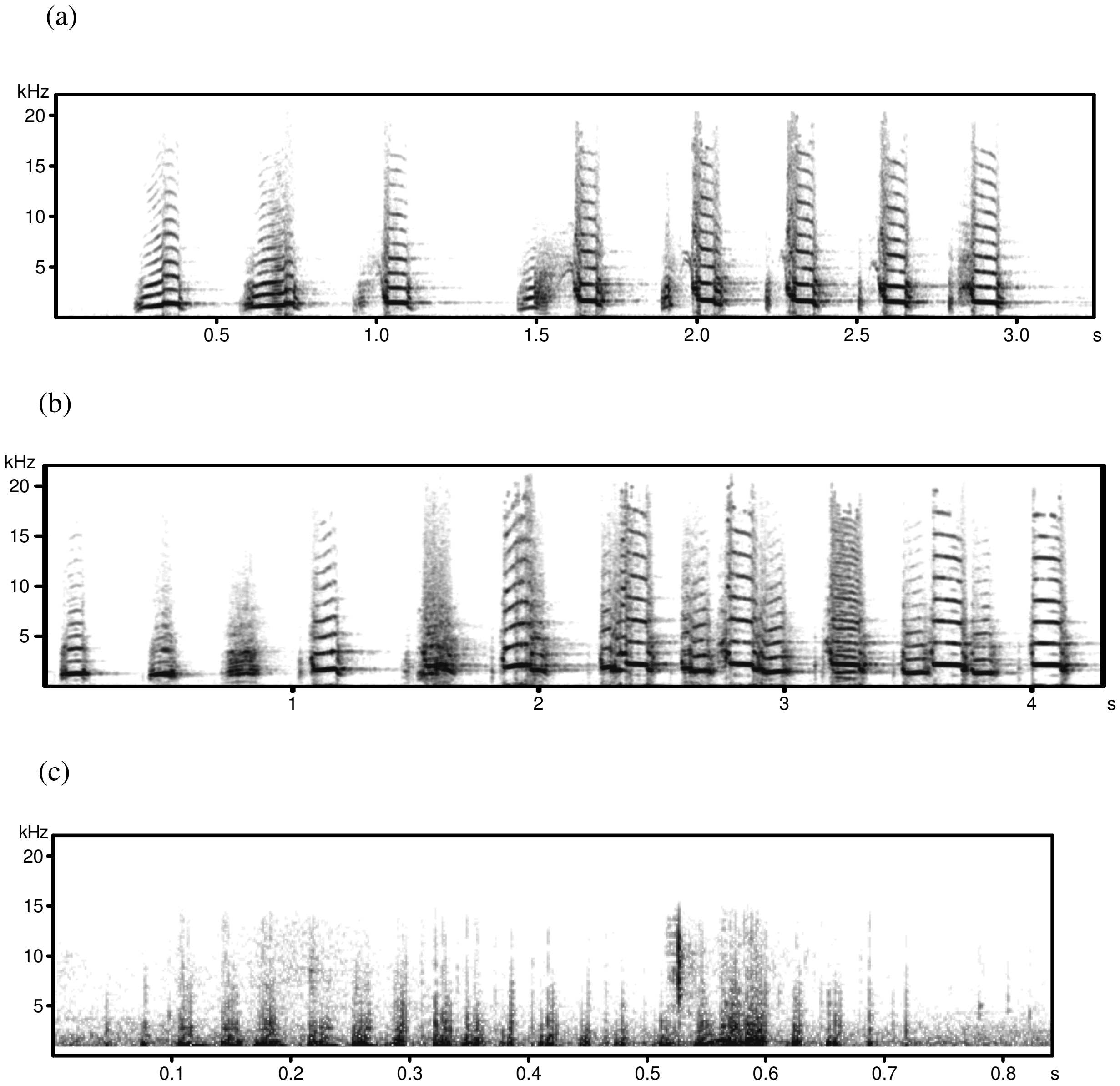
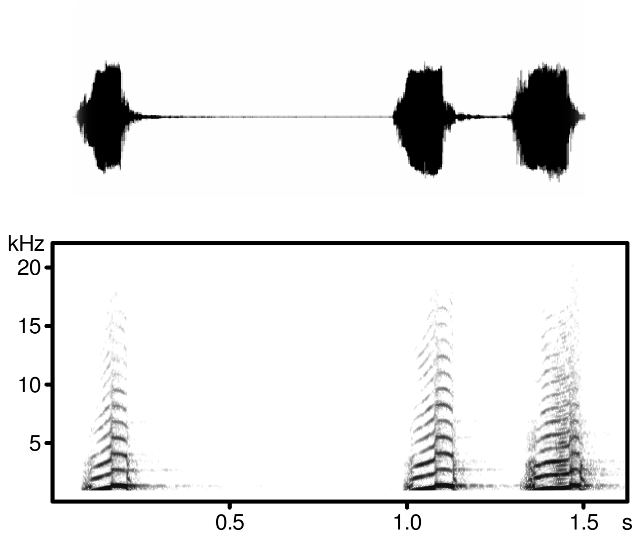


Figure 1. Vocalization Spectrograms

Spectrograms of vocalizations include (a) a solo call, (b) a pair of overlapping calls, referred to as a duet, and (c) a purr. Spectrograms were generated using Avisoft SASLab Pro, with 512 FFT length and Blackman window.

(a) Upsweep



(b) Ladder

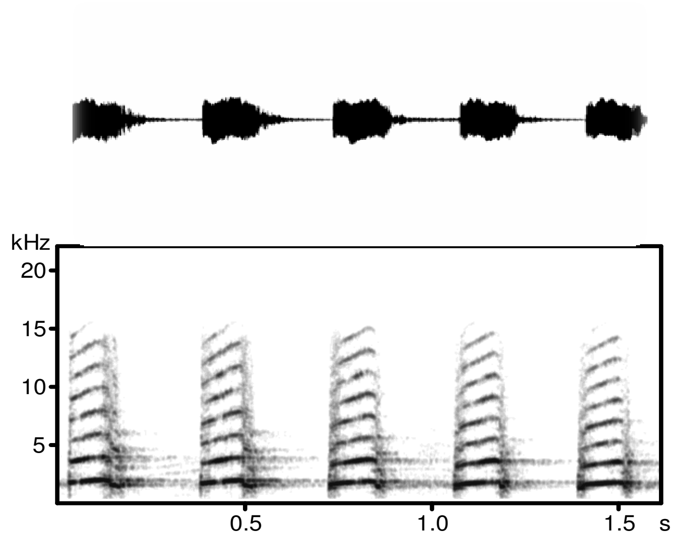


Figure 2. Note Type Spectrograms

Examples of note type waveforms (top) and spectrograms (bottom): (a) upsweep notes (U), (b) ladder notes (L), and (c) two-part notes (T). Spectrograms were generated using Avisoft SASLab Pro, with 512 FFT length and Blackman window.

(c) Two-Part

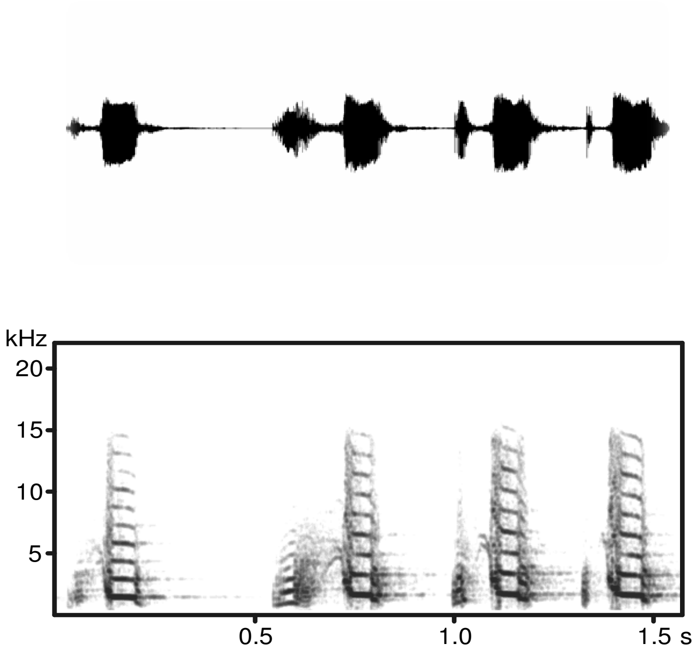


Figure 2. Continued.

Figure 3. Stimulus models

Stimulus models used during the manipulation phase include (a) dog model placed on the exterior of the exhibit, (b) penguin control model placed on the exterior of the exhibit, and (c) plant control stimuli also placed on the exterior of the exhibit.

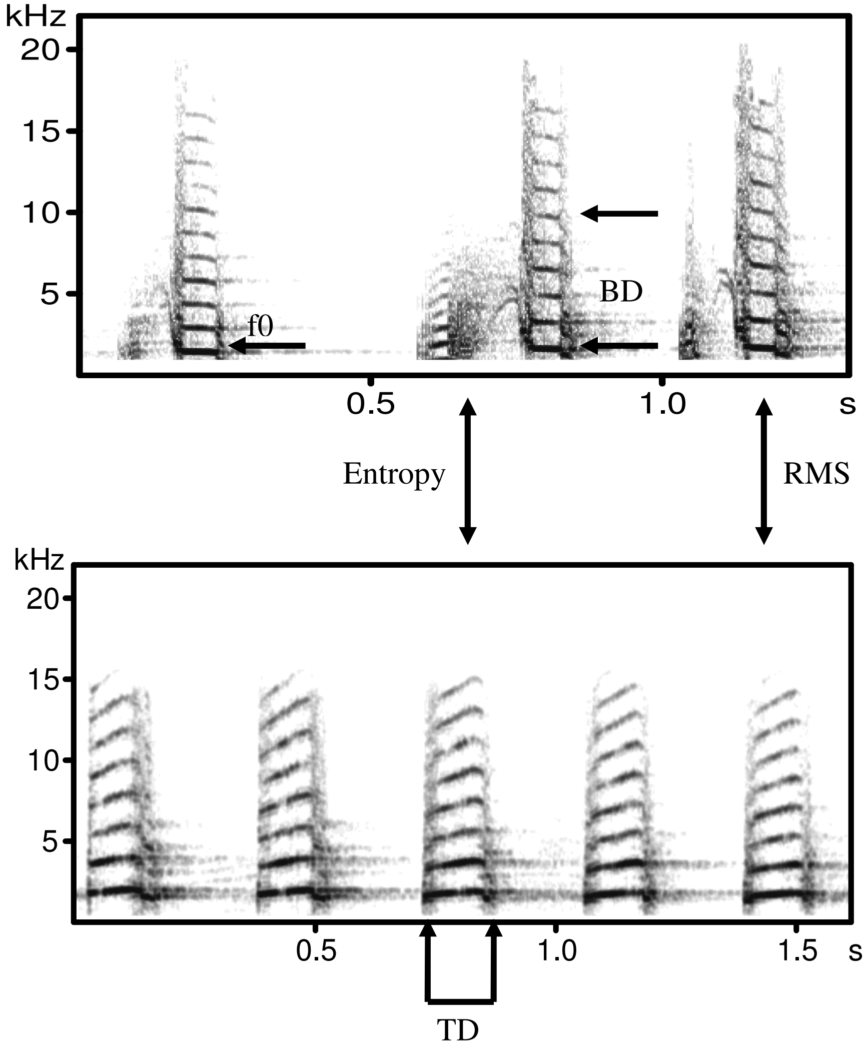


Figure 4. Acoustic Parameter Measurements

Spectrogram illustration of acoustic parameter measurements of seriema notes. TD = total note duration; f0 = fundamental frequency; BD = bandwidth, RMS= root mean squared. For RMS, the lower illustration shows higher RMS (higher intensity) than the upper illustration. For entropy, the upper illustration shows higher entropy (disorder) than the lower illustration.

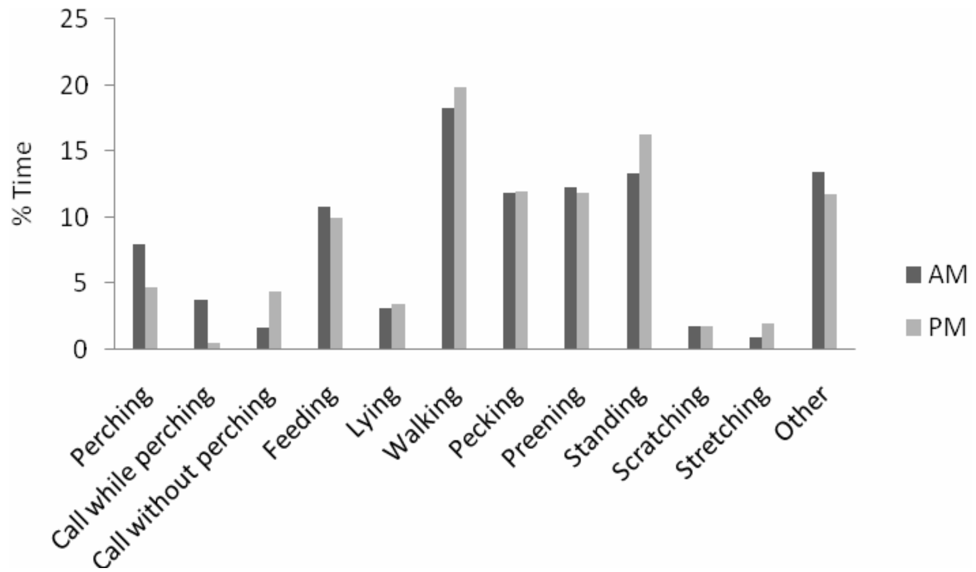


Figure 5. AM and PM Rates of Behavior

Mean behavior rates were converted to percent time for common behaviors.

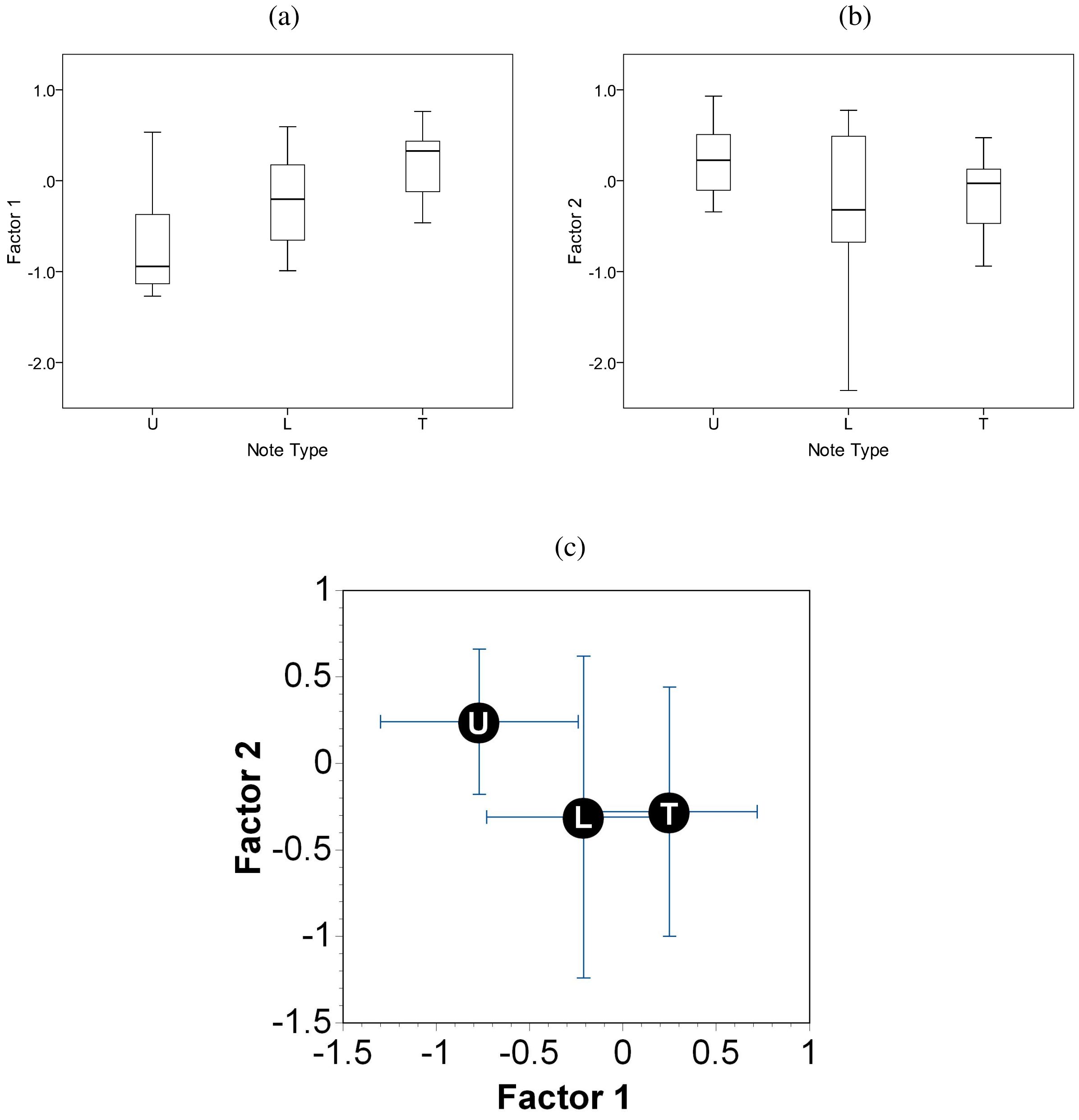
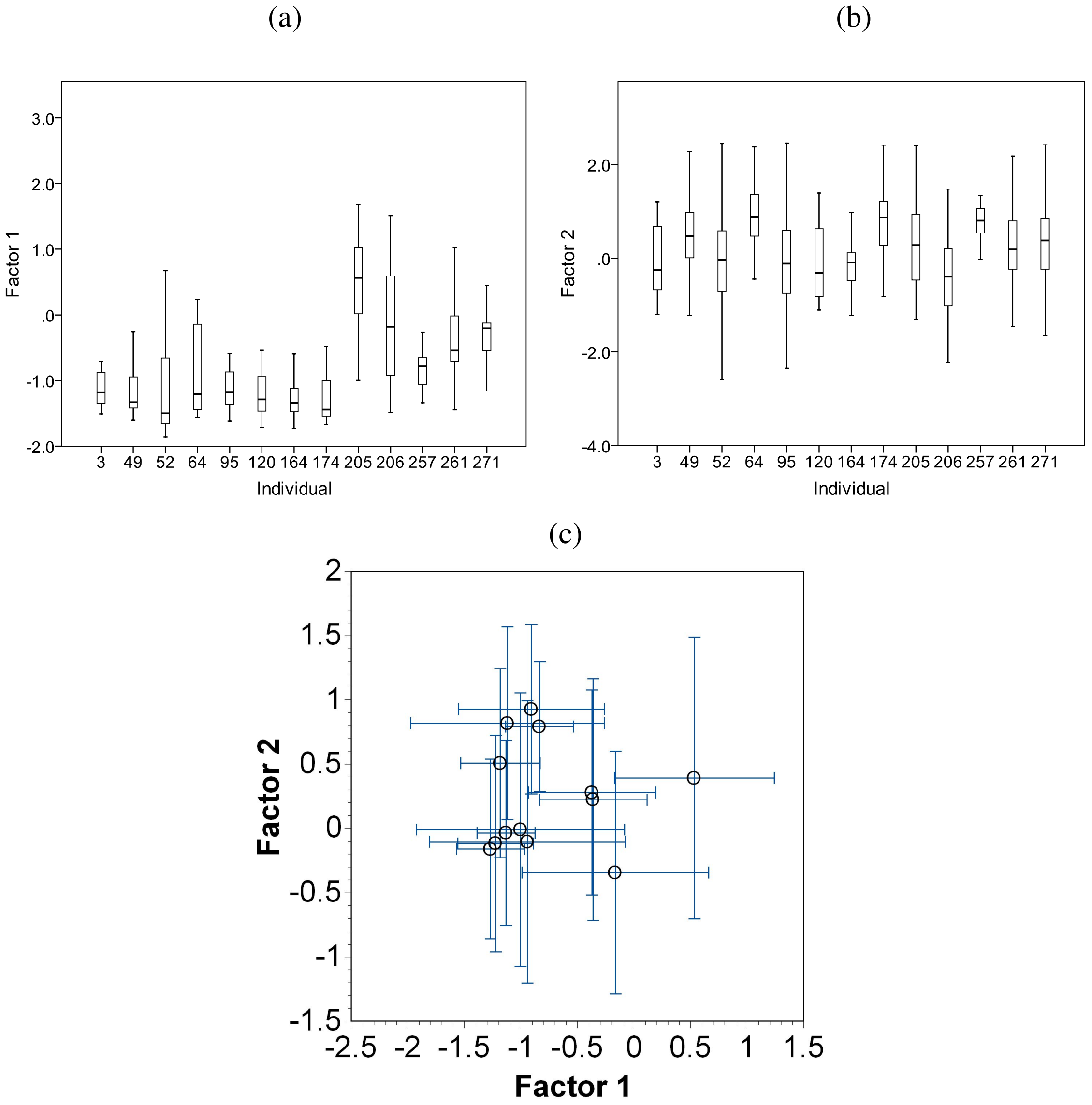


Figure 6. Individual Note Type Factor Scores

(a) Factor 1 scores primarily include RMS, frequency, bandwidth, and entropy and (b) Factor 2 scores primarily include duration. Each graph compares upsweep (U), ladder (L), and two-part (T) note types. (c) Mean (circles) and standard deviations (error bars) factor scores for the three note types.


(a)

(b)

(c)

Figure 7. Individual U Note Factor Scores

Individual variance for each note type including (a) factor 1 scores, (b) factor 2 scores, and (c) overall individual differences, with the circles representing mean factor scores and the error bars representing standard deviations.

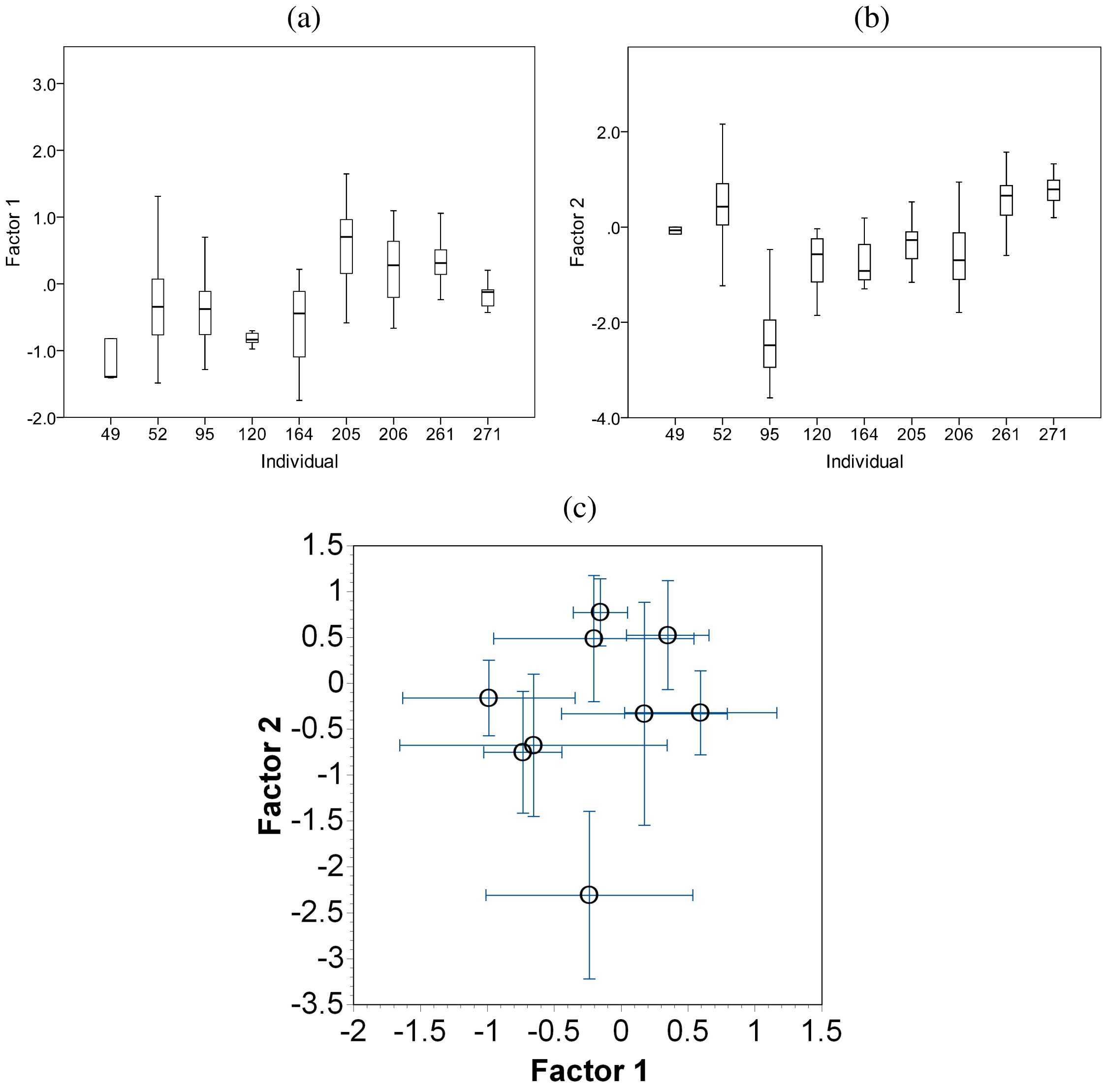


Figure 8. Individual L Note Factor Scores

Individual variance for each note type including (a) factor 1 scores, (b) factor 2 scores, and (c) overall individual differences, with the circles representing mean factor scores and the error bars representing standard deviations.

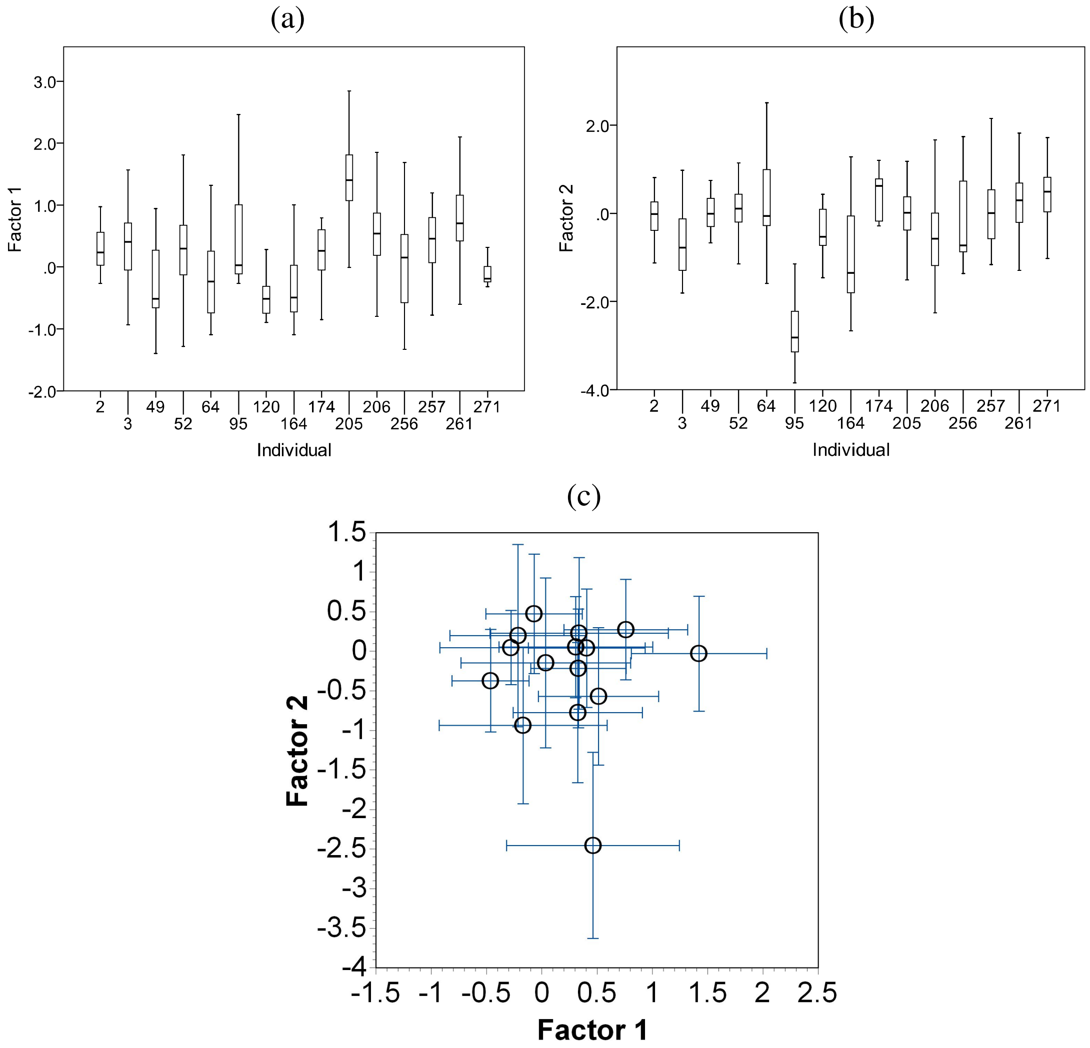


Figure 9. Individual T Note Factor Scores

Individual variance for each note type including (a) factor 1 scores, (b) factor 2 scores, and (c) overall individual differences, with the circles representing mean factor scores and the error bars representing standard deviations.

Vita

Ami Elizabeth Padget, daughter of Tom and Vicki Padget, was born in LaGrange, GA on July 4, 1981. She graduated with her Bachelor of Science in Biology in 2004 from Georgia College and State University in Milledgeville, GA. After working at Marine Life Oceanarium in Biloxi, MS she moved to Knoxville, TN and took a job as a bird and mammal trainer at the Knoxville Zoo. Soon after, she entered graduate school at the University of Tennessee in 2006 to pursue a degree in animal behavior. After graduate school, she plans to pursue a position in the animal behavior field and to continue to follow God's plan for her life.