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A STUDY OF CAPTIVE BROWN-NOSED COATIS, NASUA NASUA: AN ETHOGRAM AND CONTACT CALL ANALYSIS

A Thesis Submitted in Partial Fulfillment of
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Master of Arts

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ABSTRACT

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This study investigated the behavior and communication of captive brown-nosed coatis, Nasua nasua. An ethogram was obtained by observing and recording the behaviors of a group of five animals at the Denver Zoological Gardens in Denver, Colorado. Contact calls were recorded and analyzed using sound spectrographs. All vocalizations heard were paired with the behavioral context in which they were emitted to reveal the potential function of the call. Ethogram results indicated behaviors that are similar to those found in wild coatis. Vocalization analysis indicated that the coati contact calls contain signature frequencies. These individual contact calls would be beneficial to this social species in maintaining contact with relatives. The coatis also emitted ultrasonic frequencies in their contact calls. Individual acoustic frequencies and ultrasound use would be beneficial for this social species in maintaining contact in dense vegetation while minimizing detection by predators.

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CHAPTER I

INTRODUCTION

Animal communication is an integral part of the study of animal behavior. Understanding communication in animals helps us to gain insights on the behavior, ecology, and evolution of animals.

Mammals communicate in many ways: tactile, chemical, visual, and acoustical. One of the most complex is acoustic communication. Vocal communication is used in many contexts in animals, such as parent-offspring relationships, aggressive encounters, alarm calls, and sexual displays. Variation in calls encodes information about varying motivations of the caller (Morton 1977). Sieber (1986) found that raccoons (Procyon lotor) use chitters (low intensity and several syllables in length) and whistles in individual identification between mother and cub. Ringtails (Bassaricus astutus) also emit a chitter as a social-attractive (Tembrock 1963).

Acoustic signals may also code information concerning the degree of predation risk. Vervet monkeys (Cercopithecus aethiops) give specific calls for different predators (Seyfarth et al. 1980). Blue tits (Parus caeruleus) give distinct calls for predators at different distances (Klump and Curio 1983). Different vocalizations for aerial and land predators are displayed by the ground squirrel (Citellus beldingi) (Sherman 1985). Willey and Richards (1981) believed that further vocalization studies will be important in understanding the ecology of communication in procyonids.

However, acoustical messages express only a piece of the information at a time and when paired with a particular behavior, a more "complete" message is sent. Sounds may be considered components of certain sequences of behavior. Therefore, before the potential function of vocalizations can be understood, one must identify the context in which the vocalization is given. An ethogram is a vital tool in this process. An ethogram is a "precise catalogue of all the behavior patterns of an animal" (Eibl-Eibesfeldt 1970). This list of behaviors is achieved through careful observation. Often it is difficult to perform a complete ethogram in the wild due to the movements of the animal. A captive population, on the other hand, can be easily observed for long hours, under specific conditions, at different times of the day, and at particular times of the year. A captive situation also allows a full range of vocalizations to be heard and the properties of acoustic signals may be accurately recorded and measured.

The coati, genus Nasua, is native to Central America, Mexico, and the southwestern United States (Kaufmann et al. 1976; Taber 1940). The species occupies diverse habitats including rain forest and riparian areas. Female coatis travel in family groups called "bands" and are able to keep in contact with one another through contact calls (Kaufmann 1962). These calls are important to the cohesion of the band members, especially in the dense vegetation they inhabit. Captive and wild coatis may display behavioral differences specific to their environment. However, Smith (1980) reports a "remarkable similarity between the social behavior of the captive and wild coati." To date, no study has quantitatively measured coati contact calls. If captive-raised coatis are to be introduced into their natural habitat, knowledge of captive-raised and wild coati communication (and potential differences between the two) may be essential to successful reintroduction.

The goals of this study are to contribute to our knowledge of animal communication and our understanding of the potential function of animal vocalizations. Using coatis, these goals will be accomplished by: 1) developing a complete ethogram for captive coatis, 2) determining if coatis have individual signature frequencies in their contact calls, and 3) quantifying the differences in contact calls with regards to frequency and duration.

CHAPTER II

LITERATURE REVIEW

Coatis, first seen in the United States in 1892, are one of the largest members of the family Procyonidae (Mehren 1986). Males weigh 5.5-7.0 kg (12-15 pounds), while the smaller females weigh 4.5-5.5 kg (10-12 pounds) (Mehren 1986). They possess a pointed rostrum which assists their sharp claws in digging up food such as insects. A white mask is present on the eyes and juveniles possess a ringed tail (Hoffmeister 1986). They are closely related to the raccoon, but are diurnal. Research has shown that coatis possess a reflective tectum in the eye, a structural adaptation to nocturnality, supporting the likelihood of coati evolution from a nocturnal ancestor (Chausseil 1992).

In Central and South America, coatis live in humid forests from sea level to nearly 2900 m (9600 feet) (Leopold 1959). Barro Colorado Island in Panama, the site of a coati field study, has wet and dry seasons with temperatures ranging from 21-32 ^{o}C (70-90 ^{o}F) (Kaufmann 1962). The United States coatis live primarily in south-western oak woodlands and riparian habitats; coatis infrequently have been observed in open grasslands and desert areas (Wallmo and Gallizioli 1954). The coati does not seem to be extending its range in the United States (Kaufmann 1984).

There has been some disagreement as to species identification. Hall (1981) believed there are two species: *Nasua narica*, found in the United States and Argentina and *N. nelsoni*, found on Cozumel Island, Mexico. Bisbal (1986) described *N. nasua* in Venezuela while Handley (1966) believed that the term *N. nasua* should be used to describe North American coatis only. Risser (1963) studied the coatis in southern Arizona and referred to them as *N. narica*, but these coatis have also been referred to as *N. nasua molaris* (Hoffmeister 1986). Decker (1991) provided the most recent study regarding the systematics of the coati. She recognized only two coati species: *Nasua nasua*, from northern South America to northern Argentina and Uruguay, and *N. narica*, which extends from southern Arizona and New Mexico throughout Mexico and Central America. This researcher will follow Decker's proposal.

Social Structure

Adult female coatis and their young form unstable groupings along with other related coatis, such as sisters and cousins, called "bands" (Kaufmann 1962). Although the females nest alone, they rejoin the band when their young are six weeks old (Russell 1981). Many bands may aggregate and form a larger, temporary group, even with females without young (Kaufmann 1962). Kaufmann (1962) has indicated band sizes of approximately 10-13 individuals, while other studies report band numbers as high as 25 individuals (Gompper and Krinsley 1992). These bands are not stable and some individuals may leave for days. Mothers and their young tend to stay together, while females without young are more apt to wander off alone. Some young animals, not aware of their mother's departure, may be left for days in the care of the rest of the band (Kaufmann 1962). These splits may be accidental, occurring when groups move on while some individuals stay behind to forage (Kaufmann 1962).

Bands generally do not forage cooperatively. The coatis travel daily in search of fruit, invertebrates, small vertebrates, amphibians, and arthropods (Kaufmann 1962; Bisbal 1986). Fruit is only available from February to August in Panama, and Ingles (1957) reported the Yucatan coatis eating unusual items such as stinging ants, wasps, hornets, scorpions, and tarantulas. They are able to handle these "venomous" creatures by rolling them on the ground to remove stingers, hairs and scales (Ingles 1957).

Coati males remain solitary during most of the year. Males forage and travel alone and associate with bands only during the mating season, which is December through February (Panama; Kaufmann 1962). Males coming into contact with other males will compete violently (Lundy 1954). Russell (1981) reported that males approaching bands outside of this season are usually chased away by adult females and male sub-adults; sub-adults will leave the band at two years of age and become solitary. A few friendly interactions between males and bands at other times of the year were recorded by Russell (1981) and may indicate that males can recognize their own offspring from the previous year. From February to November in Panama, the males become more aggressive, fight more, and their general conditions weakens as determined by the poor state of their fur (Smythe 1970).

Males forage alone for fruit, amphibians, invertebrates and small vertebrates (Kaufmann 1962). They have been observed to feed on parrots (Amazonas species), agouti juveniles (Dasyprocta punctata), and various snakes (Smythe 1970). Although coatis are diurnal, males tend to extend their foraging activity to hunt the nocturnal spiny rat (Proechimys species). This is due to the reduction in food resources and the intense competition with bands (Smythe 1970).

Intraspecific Interaction

Coatis engage in mutual grooming throughout most of their lives. However, there is distinct social order as to who may groom and who may be groomed by other individuals, although there is no fixed hierarchy in the band. When grooming, coatis sit head-to-tail and gently, but rapidly, bite the fur of the other with their incisors. Grooming occurs during the mating and non-mating seasons (Kaufmann 1962). Open wounds are often groomed, which contributes to cleanliness and increased rate of healing (Russell 1981). Grooming may occur with more than two coatis at a time, and individuals move in and out of the grooming sessions (Kaufmann 1962).

Juveniles generally are groomed by their mothers. Sub-adults are groomed by their mothers or other adult females in the band and adult females are groomed by their own young or by an adult male during the breeding season (Kaufmann 1962). Adult males are only groomed during this season, by adult females, which leaves their coat in poor condition the rest of the year (Kaufmann 1962).

Coatis are not always peaceful and social (Kaufmann 1962). Fighting does occur between coatis, but is rarely seen within a band. Hostility between bands is minor and usually occurs during feeding at the same fruit tree. Bands that meet may grunt, squeal and assume a head-down posture or rush each other (Kaufmann 1962). The two bands will then go their separate ways. Home ranges may overlap and hostility is provoked by resource competition. Burger and Gochfeld (1992) found that solitary males drank at small waterholes, while bands drank at larger ones. This increases their exposure to predation, but decreases the competition for drinking space.

Adult male coatis have fairly hostile relationships with each other. Kaufmann (1962) reported a dominance hierarchy between males which frequent similar feeding grounds. When fights occurred, they ended in ripped flanks, torn ears and lips, and injured eyes (Kaufmann 1962).

Males also have antagonistic relationships with adult female coatis in bands. Usually a male will be chased away from the band several times before retreating. Male sub-adults will also cause a male to retreat, especially if adult females are nearby. Occasionally, if a male confronts a sub-adult, the youngster will chitter until its mother appears and the male will be chased off (Kaufmann 1962). Russell (1981) has documented a male coati attacking and eating several young coatis.

During the mating season there is a change in the social behavior between male and female coatis. In general, "hostility between adult males increases, but decreases between adult males and members of a band" (Kaufmann 1962). Although the acceptance is apprehensive, mutual grooming, joint foraging, sleeping and copulation behavior is seen.

Communication Patterns

Communication occurs when an individual uses specially designed signals to modify the behavior of others (Krebs and Davies 1987). Coatis use many methods for communication: visual, vocal, tactile and olfactory. Their visual communication consists of various postures displayed in particular situations. For instance, a nose-up position is assumed during friendly coati-coati encounters and is often accompanied by vocalization while a head-down posture commonly precedes attack (Kaufmann 1962). Tail-twitching occurs after alarm and may indicate frustration (Kaufmann 1962).

Coatis are very vocal and they use a wide range of vocalizations in varying contexts. An individual may grunt if separated from the group, during male-male encounters, during mounting of females, and during general excitement (Kaufmann 1962). Barking occurs as an alarm and is followed by a "freeze" reaction by other coatis or by fleeing. Soft chittering, "a rapid series of high pitched, birdlike sounds," accompanies mutual grooming, while a louder chittering can be heard from young separated from their mothers or during "play fights" (Kaufmann 1962). Smith (1980) and Kaufmann (1962) also reported a loud chitter, often several syllables in length, elicited in aggressive encounters and accompanied by fighting, swatting, or retreating. During actual fights, coatis may squeal and male-male encounters often induce a "chop-chop" sound followed by tail-twitching and a head-down posture (Kaufmann 1962).

Coatis also use their olfactory sense in communication. Urine rubbing occurs when a male urinates on a tree or shrub during the mating season or when two males meet (Kaufmann 1962). Perianal sniffing has been observed between males and females during the mating season, but does not necessarily follow with copulation. This behavior has also been seen during social grooming sessions (Kaufmann 1962).

An ethogram is the compilation of the repertoire of behaviors exhibited by a particular animal which is constructed by observation in a captive and/or field setting. To obtain a full ethogram, the species must be observed at all hours of the day and daily throughout the year to represent the full range of behaviors adequately. Its use varies, but can be used to detect changes in an animal's physical condition, to reintroduce an animal into the wild, and to determine differences between the behaviors of captive and wild animals. Few ethograms have been constructed regarding coatis. Smith (1980) presented a detailed ethogram of N. narica in captivity and the behaviors of coati in Panama were also observed (Kaufmann 1962). Coatis produce a variety of vocalizations which may functionally correspond to particular behaviors found in an ethogram study. Many studies have alluded to the diverse vocalizations, but none has documented spectral analysis. In fact, Kaufmann (1962) states that "unless they can be recorded on tape for analysis and comparison, nothing is to be gained by splitting continua of intensity into multitudes of discrete, named signals when the contexts of the different signals and the responses to them cannot be defined and correlated with equal precision."

Many researchers have attempted to label a particular coati vocalization by simple auditory means. This is inaccurate due to the strong individuality in human hearing and discrimination. Kaufmann (1962), Smith (1980), and Gilbert (1973) have noted various vocalizations and their context (Table 1). Gilbert (1973) listed only three "families" of sounds (squeal, chirp, and grunt), but Peters and Wozencraft (1989) referred to most of these studies as "non-technical."

Researching the communication behaviors of animals is also important to the behavioral ethogram. Communication analysis allows researchers to study the motivational and structural composition of vocalizations and use the information to compare captive and wild vocalizations and in the reintroduction of an animal to the wild. Preliminary studies have produced a hypothesis as to the influence of the environment on vocalization repertoires and the structure of mammal vocalizations (Wiley and Richards 1978; Peters and Wozencraft 1989). It has been discussed that dwellers of denser habitats have more diverse vocalizations than those in an open environment due to the effects of vegetation and the propagation of sound waves (Wiley and Richards 1978). Animals must compensate for sound waves being attenuated by deflection and absorption (Wiley and Richards 1978). Birds in forest habitats use a low frequency, tonal song, while birds on the grasslands generally use a high frequency buzzing song. In fact, many ground birds will only sing in flight due to their dense environment, and aerial singing

Table 1. A comparison of the various coati vocalizations and behaviors.

VOCALIZATION	CONTEXT	REFERENCE
Soft chitter	contact call	Smith 1980
Soft chitter	during grooming	Kaufmann 1962
Loud chitter	agonistic	Smith 1980
Loud chitter	agonistic	Kaufmann 1962
Squeal	agonistic	Smith 1980
Squeal	agonistic	Kaufmann 1962
Squeal	reactive sign	Gilbert 1973
Growl	agonistic	Smith 1980
Growl	agonistic	Kaufmann 1962
Chop-Chop	friendly	Smith 1980
Chop-Chop	agonistic	Kaufmann 1962
Barking	alarm	Kaufmann 1962
Hiss	play	Smith 1980
Chuckling	breeding	Kaufmann 1962
Grunt	content/agonistic	Gilbert 1973
Chirp	content	Gilbert 1973

increases their broadcast area (Morton and Page 1992). Mangabeys (Cercocebus species) vocalize early in the morning before the sun heats up the dense canopy and creates a density gradient of moisture which is difficult to overcome (Morton and Page 1992). The canopy acts as a cathedral, sending the sounds back down and into the habitat (Geiger 1950; Wiley and Richards 1978). The weather also affects vocalizations in that wind, temperature, and atmospheric gradients may favor or disfavor some acoustic communication (Wiley and Richards 1978). If the resolution, the amount of information actually transmitted, is degraded, animals may be able to compensate by coding vocalizations in ways that have little similarity to other disturbances in the environment (Wiley and Richards 1978). They may also use redundancy (which requires instantaneous behavioral correlation with the vocalization) which allows the receiver to anticipate the entire signal from only the part heard (Wiley and Richards 1978). Intermediate frequencies (1-4 kHz) travel with "least attenuation regardless of habitat" (Wiley and Richards 1978). Wiley and Richards (1978) suggested that low frequency vocalizations would travel best in forests, while high frequencies should work best in the open habitats.

Individual vocal signatures have been identified in many social mammals and individual-specific frequencies may make it possible for recognition between animals in a species. Snowdon and Cleveland (1980) found that pygmy marmosets (Cebuella pygmaea) possess individual differences in their contact calls and are able to recognize each other according to the structure of each contact call. The variability in the duration of spider monkey vocalizations

(Ateles geoffroyi) may make it possible for individuals to recognize others due to these variances in the call structure (Chapman and Weary 1990). Cheney and Seyfarth (1980) found that vervet monkeys (Cercopithecus aeithops) could recognize their own offspring from other juveniles in the group on the basis of vocalization structure. Timber wolves (Canis lupus) have also displayed individual variances in the fundamental frequency of the howl, seemingly to communicate over long distances and keep this social species in contact (Tooze et al. 1990). Signature whistles of the bottlenose dolphin (Tursiops truncatus) were found to vary according to sex and may reflect the differences that the two sexes play in the social structure (Sayigh et al. 1990). It is also apparent that the dolphins develop a more complex vocalization repertoire after separation from the mother (Sayigh et al. 1990). Reindeer calves (Rangifer tarandus) displayed individual characteristics in their calls which may make it possible for mothers to recognize their offspring among a large herd (Espmark 1975). Macedonia (1986) found that ringtail lemurs (Lemur catta) also show individuality in their contact calls which included a positive correlation between the call similarity and kinship, indicating that the variances may be heritable. Captive evening bats (Nyeticeius humeralis) have shown individual differences in their vocalizations which may allow a mother to distinguish her young from others in the colony on the basis of heritable vocalizations (Scherrer and Wilkinson 1993). Raccoons (Procyon lotor) have shown acoustic variances in the fundamental frequencies which facilitate individual recognition between mother and cub (Sieber 1986). The mother raccoon is able to locate her cubs and can alter her use of vocalizations according to the changing needs of her young as they move out of the den and become more prone to predation (Sieber 1986). Most of these studies concerned individual-specific frequencies in the contact calls of the species. Contact calls are a form of contact behavior involving the exchange of acoustic signals (Immelman and Beer 1989). Birds use this type of vocalization when flying through dense vegetation that obscures visual contact, thus ensuring that the flock remains intact (Immelman and Beer 1989). However, individual differences in vocalizations do not always indicate individual recognition. It must be proven that signature frequencies are perceived and utilized. Playback experiments are an accurate way to show this aspect by replaying recorded vocalizations of the animals while noting the behaviors or responses elicited by the subjects. Playback studies with pygmy marmosets have indicated that the subjects responded more often to their own vocalizations, possibly due to increased vocal self-recognition or the distortion of the vocalization due to recorder limitations (Snowdon and Cleveland 1980). Playback studies observed with vervet monkeys have indicated that the mother can correctly distinguish between her own offspring and unrelated juveniles (Cheney and Seyfarth 1980). Vervet monkeys, after hearing the playback vocalizations, would approach the speakers, a behavior also seen when the monkeys vocalized around each other and approached the caller (Cheney and Seyfarth 1980). Through playback analysis it was determined that several measures (the frequencies of the two strongest bands of energy, the frequency of the lowest band of energy, and the tonal quality of the call) were the distinguishing factors used in individual recognition between the vervet monkeys (Cheney and Seyfarth 1980). Playback allows the animals to respond to recorded vocalizations and differences in response may indicate the discrimination between individuals.

It is important to quantify differences in vocalizations using frequency and duration measurements. Birds and mammals use "harsh," low frequency vocalizations when agitated and higher frequency sounds when frightened or "approaching in a friendly manner" (Morton 1977). Morton (1977) stated that due to the laws of physics, there is a direct correlation between the size of the animal and its vocalization; the larger the animal, the lower the frequency it is capable of producing. The low frequency agonistic vocalization would communicate the size of the signaler to the receiver. High frequency vocalizations work in the same manner, but it is still not clear what the adaptive value of this type of sound is to the signaler (Morton 1977). These type of vocalizations may have developed from infants who, because of their small size, were only capable of communicating to their parents for food by using high frequency sounds (Morton 1977). To quantify differences in the frequency and duration of vocalizations, many parameters must be examined. Snowdon and Cleveland (1980) used minimum, maximum, and center frequencies to measure variations. Differences in duration are always measured as a parameter of individual signature vocalizations (Espmark 1975; Snowdon and Cleveland 1980; Macedonia 1986; Chapman and Weary 1990; Sayigh et al. 1990; Tooze et al. 1990). Harmonics, which may occur, can also be measured (Espmark 1975; Tooze et al. 1990). By measuring these parameters, individual variances can be detected. After further study, by means of playback experiments, it can be determined if these variances are actually utilized by the animals for the purpose of individual recognition.

Individual recognition would be valuable to coatis because related bands travel together and the acceptance of males occurs only during the breeding season. If contact calls are in fact used to maintain contact within a group, then this vocalization might be expected to differ according to the group members, or possibly between groups. Band members may be able to contact each other and stay in close proximity using contact calls. By recognizing individuals, coatis may be able to avoid potentially aggressive interactions, while encouraging beneficial ones such as mutual grooming and social bonding.

CHAPTER III

MATERIALS AND METHODS

The subjects of this study were five captive brown-nosed coatis, Nasua nasua, at the Denver Zoological Gardens in Colorado. The coati group consisted of four adult females and one adult male. The coatis were wild born in Honduras in the Spring of 1989 and obtained at 8-10 weeks of age. The coatis were not marked, but were easily recognized by individual morphological features and color variations. The coatis were individually named by their keeper, Marlene Kumpf, and I have retained these names for clarity of discussion. "Kristine" (K) is the smallest female coati and has a dark black face. "Evelyn" (E) is slightly larger and has white eyebrows. "Linda" (L) has two golden spots on her forehead, while "Diane" (D), the largest of the females, has a thick, wiry coat. "Chulo" (C), the male, has a notch in one ear. The male is physically separated from the other coatis at all times, but is in visual and auditory range.

The coatis' enclosure consisted of a covered, 183 square meter outdoor area surrounded by a moat. This area (a human-made rock formation built in 1918) housed a platform in which window ledges, cement logs, and brick pillars provided climbing opportunities and an indoor enclosure, measuring 40 square meters, was divided into a caged area for the male and a larger caged area for the four females.

The indoor enclosure had nest boxes, logs, and ledges for the coatis. Additionally there was a portion of the indoor enclosure (from which the coatis were excluded) in which the keeper prepared their food.

Phase I: Ethogram

To identify correctly the behavioral contexts in which vocalizations occur, an ethogram was constructed for the study animals. Observations for the ethogram were gathered from January 1994 to March 1994. Sample periods were two to four days a week for approximately two to four hours each. Recorded observations total over 60 hours. Observations were made from the public viewing area outside and from the keeper's work area inside. Daily activity of the coatis was recorded from 10AM to 3PM. The coatis' behaviors were visually observed and video taped.

Data were collected regarding: 1) subject identity, 2) target of social behavior, 3) behavior, 4) location in enclosure, 5) proximity to other coatis. The time, temperature and weather conditions were also recorded daily. The introduction of a new food source was also recorded as needed.

A preliminary list of behaviors was taken from observations of wild (Kaufmann 1962) and captive populations (Smith 1980) of Nasua. Additional behaviors were added as they were observed. Other ethogram studies also added to the behavioral categories noted (Nickelson and Lockard 1978; Skinner and Lockard 1979).

Phase II: Vocalization
Recording and Analyses

Contact calls were recorded with a Uher CR 160 AV tape recorder and a Sennheiser K3-U microphone. Recordings were only obtained from the indoor enclosure to avoid aircraft noise, weather, and visitor interference. The cassette tapes operated continuously and were later paired with a video tape to match vocalization and context. Data were collected two to four days a week for two hours each day from February 1994 to July 1994. Vocalization recording totaled over 50 hours. The females were isolated from each other on two occasions so that individuals could be recorded. Isolation ensured a large sample of high quality recordings from individuals. To date, no study has quantitatively measured coati contact calls.

Analyses of the contact calls were conducted with a Kay Elemetrics Computerized Speech Lab (CSL) model 4300B digital spectrograph using a sampling rate of 50,000 Hz. The program examines the physical properties of sound wave forms and detects individually distinct patterns of frequency modulation. At least six contact calls were recorded for each individual. The calls were analyzed for acoustic variations using eight parameters, some of which were also used by Snowdon and Cleveland (1980) in their study of pygmy marmoset (Cebuella pygmaea) vocalizations. The following parameters were measured:

a) Lowest frequency of the fundamental band = FLo
b) Highest frequency of the fundamental band = FHi
c) Center frequency of the fundamental band = FCe
d) Duration of the fundamental band = FDu
e) Lowest frequency of the harmonic = HLo

f) Highest frequency of the harmonic = HHi
g) Center frequency of the harmonic = HCe
h) Duration of the harmonic = HDu

The harmonic element refers to the frequencies above the fundamental frequency band. These variables were used to determine significant differences between the coati vocalizations.

By using a S-25 Bat Detector from Ultra Sound Advice with a detachable SM2 microphone, ultrasonic frequencies were detected in the coati contact calls. The detector has a 15-200 kHz tuning range, ±1.5 kHz accuracy. The volume of the detector was set at low to medium, while the HF gain, which controls the amount of amplification before processing, was set very low so that ultrasound signals would not be truncated resulting in distortion of the signal amplitude.

Acoustic variables were examined using non-parametric statistics because the data violated the assumptions required by parametric statistics. Kruskal-Wallis one-way ANOVA was used to determine if differences existed between three or more individuals and Mann-Whitney U tests were used to make comparisons between pairs of individuals regarding the acoustic variables. In all cases significant differences between pairs were assumed when $p \leq 0.05$.

CHAPTER IV

RESULTS

The ethogram for the captive coatis at the Denver Zoo contains 59 different behaviors which were placed into ten categories (Table 2).

Rest

The coatis exhibited various sitting and lying postures at rest. The most consistent rest position was **sitting** with all feet touching a substrate, but occasionally the coatis would "sit up" and rest their fore paws on their chest. While **sleeping**, the head was tucked down while the paws covered the face. The coatis also rested on top of each other, usually with a head resting on the nape or back of another.

Locomotion

Locomotion included any movement of the entire body, especially in getting from one place to another. **Walking** was always quadrapedal and varied from a slow pace to trotting. The coatis walked around the enclosure singly and never appeared to spend time cooperatively except during rest. **Climbing** was seen when the coatis ascended the cage or brick walls. They were also seen climbing across the caged ceiling of the enclosure while hanging upside-down. **Running** occurred when the coatis chased a bird or squirrel from the cage and when startled by a loud, unfamiliar noise. **"Bridging"** occurred when a coati braced itself between two brick walls or logs and scooted along to position itself. This was accomplished by many methods. They would either brace their anterior and posterior ends against separate structures provided for exercise, or they would brace their left and right sides at different points along a wall. **Jumping** was characterized by a coati leaping from one ledge or log to another. **Pacing**, the action of walking in a patterned way, was observed frequently while in the indoor enclosure. **Galloping** was observed only in the outdoor enclosure and was an indication of play when two or more coatis would gallop from opposite directions toward each other.

Ingestion

Searching for food included activities in which hay was moved, wood was stripped, and wildlife, such as birds and squirrels, were chased in order to obtain food. **Eating** included many food items such as bananas, grapes, apples, monkey chow, canine kibble, mice, crickets, meal worms, bread, honey and eggs. **Food cleaning** was seen when bread and kibble were dipped in water before ingestion. **Drinking** water was obtained by licking the floor of the enclosure, from the moat, or from the water dish provided. The coatis **licked** crevices in the bricks and in logs to obtain food such as honey and insects. **Regurgitation** occurred after a coati had eaten a mouse; it then reingested it. **Defecation and urination** were also observed. **Coprophagy** was observed by two of the coatis while in the indoor enclosure.

Grooming

Allogrooming included the mutual grooming of two or more coatis at a time, and occasionally all four participated. Grooming was accomplished by searching the fur of the self or another with the paws and teeth. Self grooming was seen more often than allogrooming. Scratching was seen in which an area of the skin was rubbed as if to relieve an itch. This may have been achieved by scratching with a paw or by rubbing the area against a log. Shaking, a back and forth motion of the body, was also seen.

Play

Playing was seen infrequently. The coatis tossed and dragged cardboard tubes, and rolled rocks and sticks with their forepaws and noses. Rocks were carried around and repeatedly dropped. Mutual play was also observed as the coatis would lightly pat another coati on the head or face. This was usually followed by a playful bite and licking of the forehead. Occasionally wrestling was seen between two coatis, but lasted only seconds. Lastly, many of the coatis would put the tip of their tails in their mouths and walk or run.

Affiliative

The most frequently observed contact between individuals was touching. The coatis either greeted each other by nose-to-ear contact, nose-to-nose contact or nose-to-rear contact. "Nose-up positions" in which the coatis raised their noses in the air were seen when coatis greeted each other. Perianal sniffing was very common. **Huddling** was seen when the coatis were resting or sleeping. Soft **pats** with the forepaws were given as coatis passed each other and, on one occasion, as one coati was choking, the others came over and patted her nose. **Swatting** with the forepaws was seen during aggressive displays towards each other. **Mounting** was observed between two females on two occasions.

Agonistic

Agonistic displays always included a **swat** to the other's face. **Tail lashing** was seen when a coati was upset and slapped its tail from side to side vigorously. **Wrestling** was also seen in agonistic displays, but only lasted a few seconds. Typically in these cases, two individuals would mutually grasp each other with their forepaws and tumble over. Occasionally two coatis would swat at each other simultaneously and almost appear to be **boxing**.

Tail displays

Tail displays varied, but were consistent with the associated behavior. Tails were positioned **straight up and** hooked at the end while eating or searching for food. When upset or startled, the tails became very **straight and** erect. While sleeping or resting, the tail was either **curved** around the body or **hanging straight** down off a ledge. While walking, the tail was **parallel** to the ground, but still had a small hooked end. **Tail lashing** was seen when the animals were upset or scared.

Respiratory

The coatis **panted** when distressed over a human newcomer into their caged area. **Scent rubbing** occurred when the coatis were given catnip and they would rub it all over their tail and paws. **Yawning** occurred frequently just before rest. **Sniffing** occurred frequently while the coatis walked around the enclosure. They would sniff in crevices, under food bowls and at logs. **Coughing, choking,** and **sneezing** by one coati would always attract the attention of the others. They would stop what they were doing, "freeze," and either watch the other coati or move closer to it to investigate.

Vocalizations

Chirps, single syllable vocalizations, were heard the most frequently and served as contact calls (Table 3). Chirps were emitted at any time and only emitted while the coatis were moving. A stationary coati did not emit a contact call. "D" emitted contact calls more frequently than any of the other coatis. A chitter can be described as a series of 7-8 chirps of short duration. **Soft chitters** were almost inaudible and accompanied allogrooming (Table 3). **Loud chitters** were always emitted in an aggressive situation (Table 3). **Grunting** was also heard in an agonistic setting, the frequency was very low and sounded almost dog-like (Table 3). **Ultrasound** of course was not heard but was detected in the contact call of the coati.

Vocalization Analyses

Six calls for each of the five coatis were used in the analysis. The typical contact call consisted of a fundamental element in which the mean frequencies ranged from 5-12 kHz and a harmonic in which the frequencies ranged from 10-18 kHz. Both elements made up the contact call and were present at each sonogram of the vocalizations. There were no significant differences in 1) the lowest frequency of the fundamental (p=0.1235), 2) the duration of the fundamental (p=0.0657) and 3) the duration of the harmonic (p=0.2470) (Table 4). The coatis differed significantly in 1) the FHi (p=0.0002), 2) the FCe (p=0.0028), 3) the HLo (p= 0.0004), 4) the HHi (p=0.0019) and 5) the HCe (p=0.0009) (Table 4).

Signature frequencies

The coatis displayed unique individual frequencies in their contact calls. For instance, individuals K, D, L and E had similar means of the FLo frequency, approximately 5-6.17 kHz. In the FHi frequency, they emitted frequency means ranging from 10-12 kHz. The center frequency means then ranged from 7.7-9 kHz. The duration of the fundamental element (FDu) showed no significant difference and ranged from .146-.184 seconds (p=0.0657). The harmonics differed significantly in all parameters except duration (p=0.2470). The low frequencies of the harmonic (HLo) ranged from 10-14 kHz and the high frequencies of the harmonic (HHi) ranged from 13.8-17.7 kHz. The center frequencies (HCe) ranged from 11.9-15.4 kHz, while the duration only ranged from .09-.16 seconds (Table 4).

Table 2. A list of behaviors exhibited by the captive coati, *Nasua nasua.*

Rest
Sleeping
Sitting

Locomotion
Walking
Climbing
Running
Bridging
Jumping
Pacing
Galloping

Ingestion
Searching for food
Eating
Food cleaning
Drinking water
Licking
Regurgitation
Defecation
Urination
Coprophagy

Grooming
Allogrooming
Self grooming
Scratching
Shaking

Respiratory
Panting
Scent Rubbing
Yawning
Sniffing
Coughing
Choking
Sneezing

Play
Tossing
Dragging
Rolling
Dropping
Patting
Biting
Wrestling
Walking with tail in mouth

Affiliative
Touching
Nose-up
Perianal sniffing
Huddling
Patting
Swatting
Mounting

Agonistic
Swatting
Lashing tail
Wrestling
Boxing

Tail displays
Up and hooked
Straight and erect
Curved around body
Hanging
Parallel with hook
Tail lashing

Vocalizations
Chirp
Soft chitter
Loud chitter
Grunt
Ultrasound

Table 3. A list of the vocalizations emitted in the captive coatis and their corresponding behavioral contexts.

VOCALIZATION	FORM	CONTEXT
Chirp	single syllable	contact
Soft chitter	7-8 syllables	allogrooming
Loud chitter	7-8 syllables	agonistic
Grunt	single syllable	agonistic

The results revealed that the coatis exhibited signature frequencies in their contact calls. These differences can also be seen in the direct sonogram analysis of the contact calls. Each coati also exhibited a unique pattern of the call when displayed as a sonogram. (Figures 1-5).

Ultrasound

The coatis emitted ultrasonic frequencies ranging from 30-55 kHz in their contact calls. It may be that individuals emitted unique ultrasonic frequencies but because they were tested in a group this could not be determined. When the ultrasound detector was set lower than 30 kHz and higher than 55 kHz, no ultrasound was registered.

Table 4. Means (±standard deviation) of the individual frequencies and durations of the five coatis. (N=6 per individual)

COATI	PARAMETERS							
	FLo (kHz)	* FHi (kHz)	* FCe (kHz)	FDu (Sec)	* HLo (kHz)	* HHi (kHz)	* HCe (kHz)	HDu (Sec)
K	6.17±.40	10.33±.82	7.92±.66	.184±.02	11.67±1.51	17.67±.82	13.67±1.21	.115±0
D	5.00±1.67	10.33±.82	7.67±.81	.176±.04	13.33±1.03	17.00±1.09	15.17±.98	.089±.03
L	6.00±0	12.00±0	9.00±0	.146±.04	14.00±0	16.83±.98	15.42±.49	.085±.03
E	6.17±.41	10.00±0	8.08±.20	.165±.01	10.00±0	13.83±.41	11.92±.20	.108±.04
C	6.0±0	11.83±.41	8.08±.20	.202±.17	13.50±.54	16.83±1.16	15.16±.75	.100±.02

* indicates significant differences in the parameters between individuals.

Low frequency of the fundamental band = FLo
High frequency of the fundamental band = FHi
Center frequency of the fundamental band = FCe
Duration of the fundamental band = FDu

Low frequency of the harmonic = HLo
High frequency of the harmonic = HHi
Center frequency of the harmonic = HCe
Duration of the harmonic = HDu

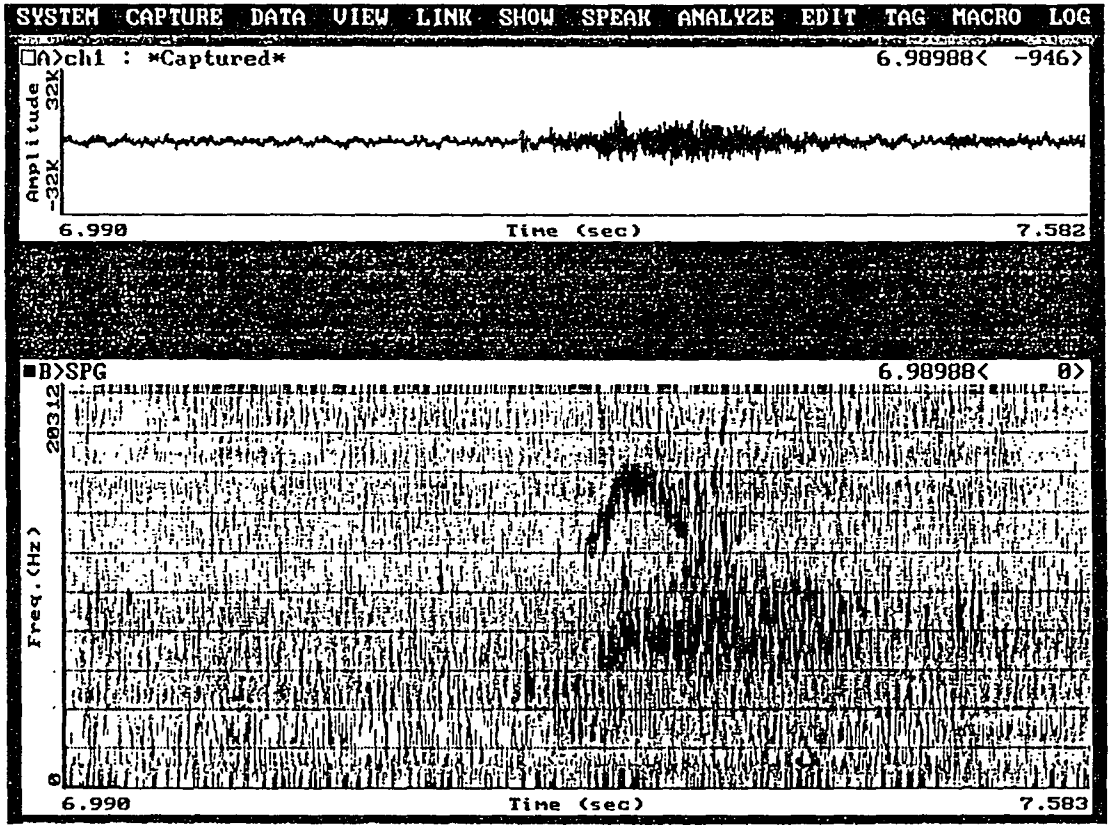

Figure 1. A representative spectrogram of the contact call of the adult female "D."

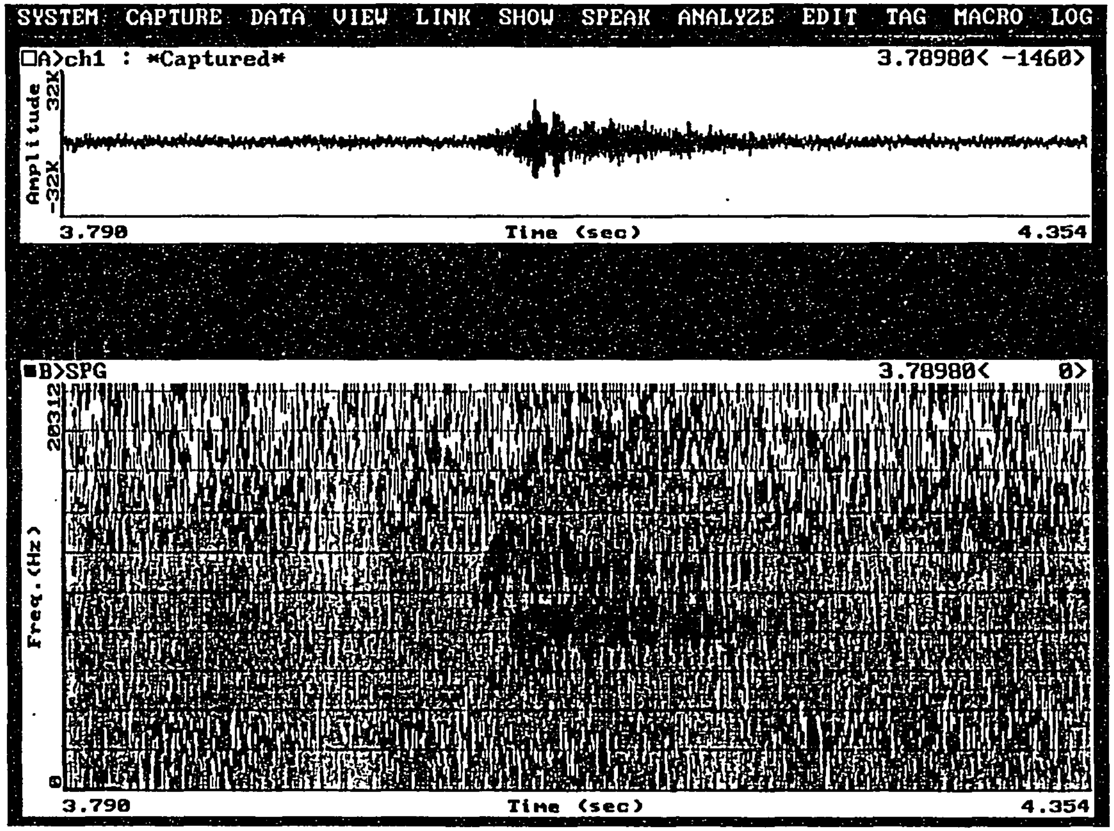

Figure 2. A representative spectrogram of the contact call of the adult female "E."

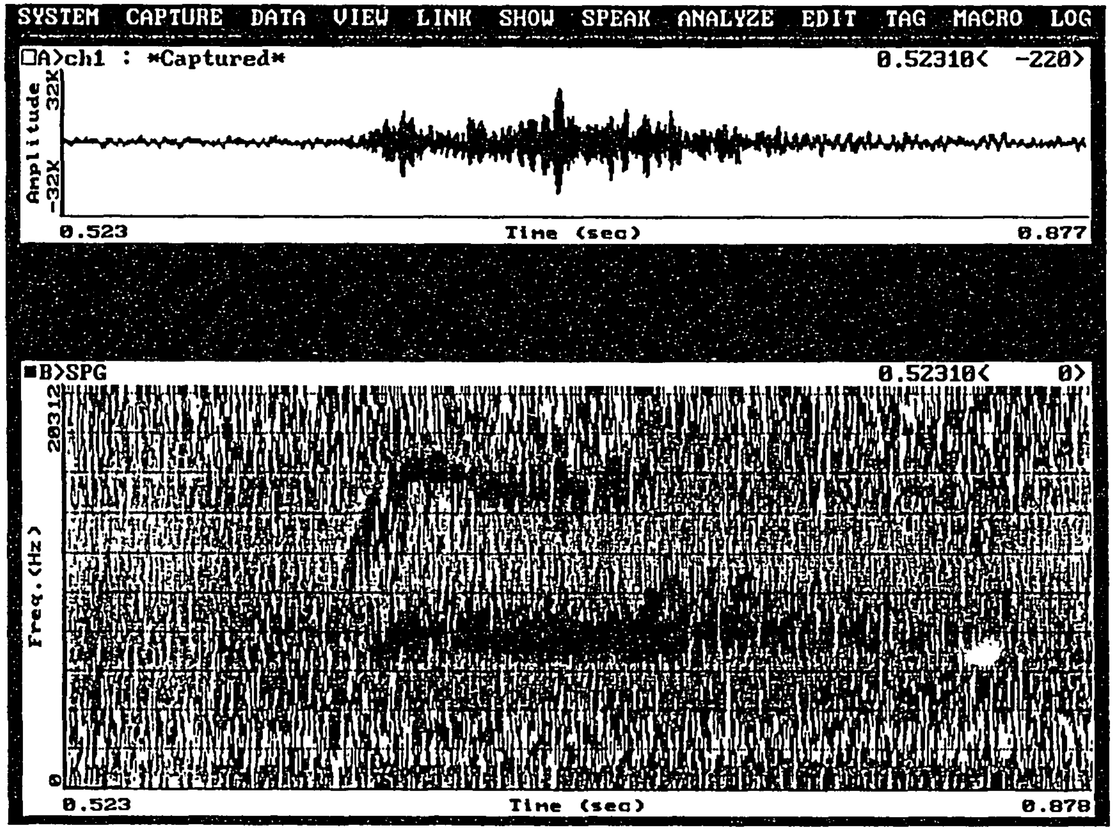

Figure 3. A representative spectrogram of the contact call of the adult female "K."

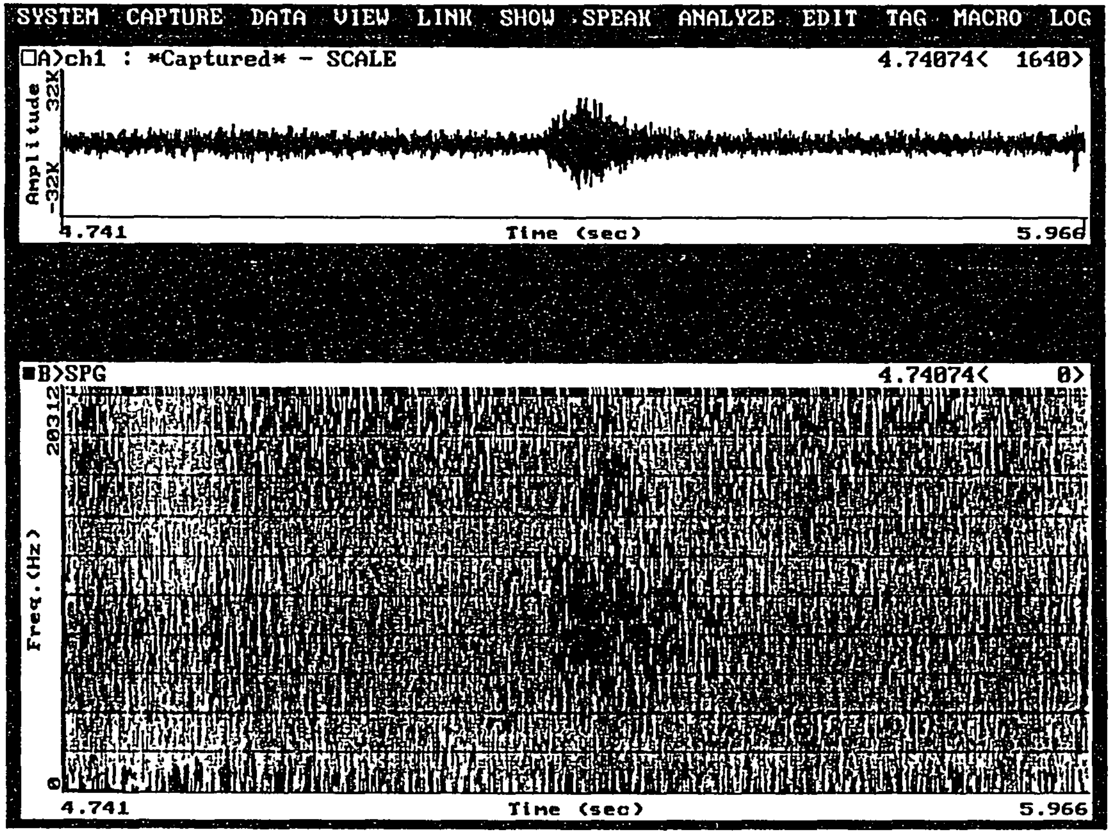

Figure 4. A representative spectrogram of the contact call of the adult female "L."

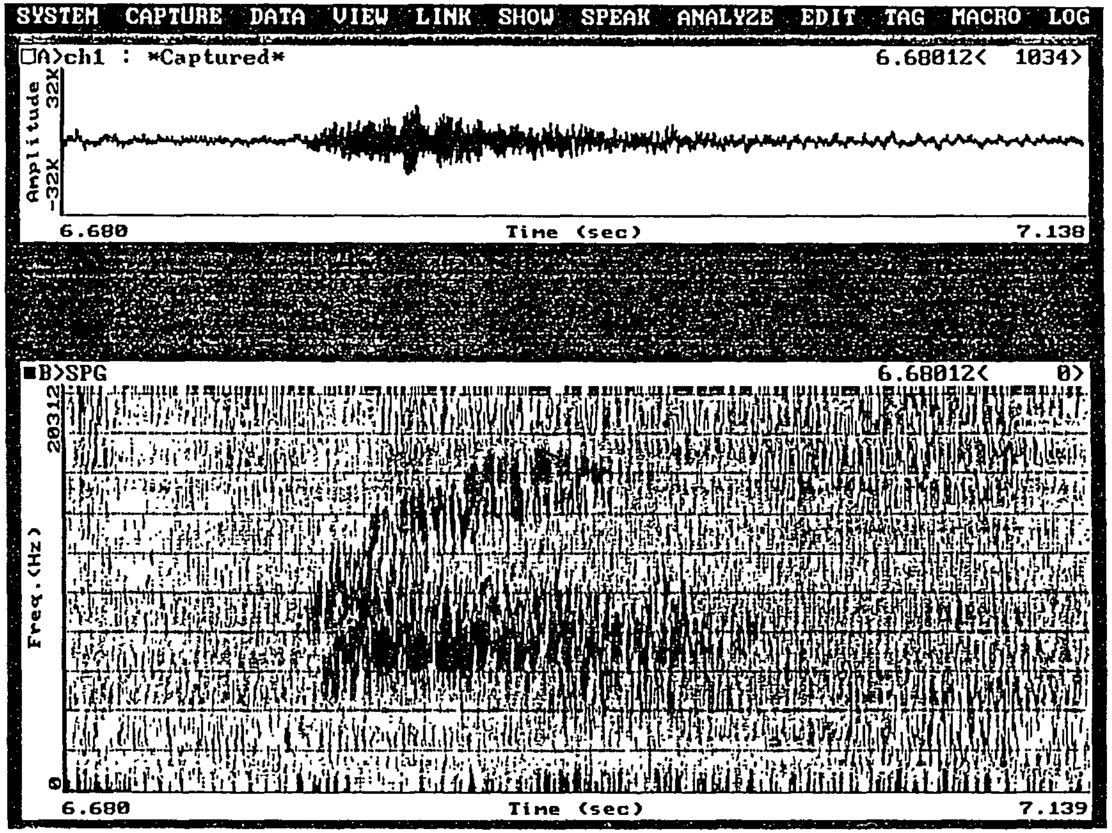

Figure 5. A representative spectrogram of the contact call of the adult male "C."

CHAPTER V

DISCUSSION

Ethogram

The ethogram presented for the brown-nosed coatis in this study (henceforth: Denver coatis) was similar in many aspects to Smith's (1980) ethogram of captive white-nosed coatis (Nasua narica) and that recorded by Kaufmann (1962) of free-ranging coatis (Nasua narica) in Panama. However, important differences in behavioral repertoires were observed in this study (Table 2).

Play was seen rarely between the Denver coatis and most often involved solitary play with a novel item such as a rock, food dish or stick. Another play behavior, in which an individual would walk and/or climb with its tail in its mouth, has not been documented in any previous coati study. In contrast to Smith's (1980) observations of mutual play in several forms, the Denver coatis exhibited only wrestling (between two females).

Captive studies have indicated that naturalistic settings favor the expression of normal behavior (Maple and Finlay 1987). Animals in naturalistic habitats, by both social and physical methods, have shown an increase in activity and have also displayed behaviors similar to their conspecifics in nature (Maple 1979). The Denver coatis climbed frequently on logs and cage bars and which was comparable to the climbing done by the wild coatis while fleeing from predators or when nesting (Kaufmann 1962). Smith (1980) believes that certain "natural" elements of the captive exhibit, such as logs and dirt, must be offered to stimulate "environment-oriented behaviors." Natural settings allow animals to express the full repertoire of behaviors, by providing similar elements in the captive situation that are also found in the wild. For instance, because the coatis are omnivorous, they engage in foraging bouts that may cover several areas and several types of terrain. By providing foraging opportunities in logs, dirt, ledges and rocks, the captive coatis can express their natural foraging techniques. Most of these opportunities should be placed near the ground because the coatis forage principally on the tropical forest floor (Kaufmann 1962). The higher areas available, such as trees and ledges, provide an escape route from potential predators or strangers in the captive situation. In the wild, coatis flee from predators by climbing trees (Kaufmann 1962). Nest boxes should be placed off the ground as the wild coatis nest in the trees. Adequate shade and sun must also be proportioned in the captive exhibit so that the captive coatis experience both, just as the wild coatis would in the tropical environment. Realistic behaviors are expressed in those captive exhibits that mimic the natural environment and social situations of an animal.

To be successful, the captive setting must not simply imitate the natural landscape. Maple and Finlay (1987) have indicated that appropriate social groupings also play a role in the behavioral patterns of the animals. By placing a captive group of related female coatis together, a zoo replicates the social band found in the wild.

Separating the male coati during the non-breeding season also simulates a wild situation. With this situation, natural social interactions are allowed to occur, revealing that in captivity the full behavioral patterns of the coatis. Clevenger (1987) redesigned a captive coati exhibit and reports that the naturalistic setting (including dens, dirt, foliage, ledges, trees, sun and shade) and social grouping, increased activity in the coatis (Nasua nasua). With the increase in activity came the increase in zoo visitor experience because the coatis were visible in the exhibit 95% of the day while actively foraging and socializing (Clevenger 1987). In other habitat modifications, chimpanzees exhibited reduced cage stereotypies (Clarke et al. 1982), and gorillas and orangutans (in separate habitats) both showed reduced aggression (Maple and Finlay 1987). Maple and Finlay (1987) have indicated that enriched animal behaviors also improve visitor experience by increasing the activity level exhibited by the animals. The visitors may tend to stay longer at the exhibit, become interested in the status and life history of the animals, and become educated regarding the species' counterparts in the wild. Thus education, one of the primary goals of zoo organizations, may be enhanced.

Natural behavior is valuable to the life of the captive animal in many respects. It is important to the animals so that they are able to interact normally, possibly increasing their reproductive success in the captive setting. Also, if captive animals are to be raised for reintroduction into the wild, natural behaviors must be promoted. For instance, captive animals not encouraged to forage may be unable to do so properly in the wild and may starve. Animals whose environmental and social settings do not resemble natural conditions may also display abnormal communication behavior. Recent studies have revealed that captive golden lion tamarins (Leontopithecus rosalia) have reduced and seemingly juvenile communication abilities (Ruiz-Miranda 1993). If reintroduced, these animals may not be selected for mating or able to alert conspecifics of predators due to their decreased communication abilities.

Gentle contact, performed by soft pats and touching with the paws, face or body, was seen also by Smith (1980) as an affiliative behavior. This behavior was most frequently exhibited when the Denver coatis approached each other; often a stationary coati would pat a passing coati. Smith (1980) believes that this type of social interaction maintains "friendly relations" between the females. The contact that exists between the female coatis appears to function in maintaining the sociality of the band. Strong social bonds would be advantageous in predator detection and defense. For example, Janzen (1970) observed members of a coati band attacking a boa (Boa constrictor) which was constricting a juvenile coati. This altruistic behavior is often seen in social animals which are able to alert conspecifics to a predator or engage in the rescue of a victim.

Agonistic displays by the female Denver coatis always included a swat to the other coati's face, which would frequently encourage "boxing," an act in which both coatis swatted simultaneously at each other. Smith (1980) has recorded many more agonistic behaviors in her study of captive coatis than were observed among the Denver coatis. Two possible reasons exist for this difference. First, Smith's group contained a male which was in contact with the females for three months. In the wild a male may be in contact with the band for only a month or less (Kaufmann 1962). In wild situations males were observed to leave for days and then return, or forage nearby but stay with the band every day (Kaufmann 1962). These males were able to leave the band at any time, unlike the captive male in Smith's study. Outside of the breeding season, males were not welcome into the band (Kaufmann 1962). The male Denver coati was maintained in an enclosure adjacent to, but separate from the females. In fact, part of this male's ear had been bitten off in a previous attack by one of the female coatis. Smith (1980) described "extreme disturbance" of the females when the male was first introduced into the exhibit. Although Kaufmann and Kaufmann (1963) suggested that male coatis should be placed in an exhibit with females, Smith (1980) stated that the males should be separated from the females during the non-mating season. This would imitate the wild situation more closely. A second reason that Smith's coatis displayed more agonistic behaviors is that they may not have been related females. Typically females remain within their natal band and the males disperse (Kaufmann 1962). The Denver coati females were siblings. In summary, the Denver coati "band" more closely resembled that of a natural social situation in the wild.

Coati tail displays were often observed in this study but have not been recorded before in captive settings. In the liontail macaque (Macaca silenus) it is believed that tail displays may play an important role in communication (Skinner and Lockard 1979). In dominant male macaques the tail is erect and slightly arched, while in other group members, the tail hangs loosely (Skinner and

Lockard 1979). An erect tail was seen in females in "fear provoking situations" (Skinner and Lockard 1979). LaGory (1981) studied the possibly communicative role in the tail-flicking behavior of the white-tailed deer (Odocoileus virginianus). He found that tail-flicking may alert other deer to a disturbance, but it did not encourage retreat. This tail-flicking may also facilitate group cohesion and contact in that the white of the rump can be exposed to other deer, but covered with the tail to prevent the detection of a predator (LaGory 1981). Based on the results of the macaque and deer studies, the tail displays of the coati may also follow the context of particular behaviors. When startled, the coati displays a slightly erect tail, similar to the erect tail of the white-tailed deer when alerting conspecifics. This erect tail may also alert other coatis of a disturbance; however, as with the deer, the coatis do not flee, but only freeze and stand displaying the erect tail. In this situation the coatis are warned of a disturbance through the erect tail posture and may simply freeze to avoid further detection.

Coughing, sneezing, and choking by conspecifics (as well as other outside noises, such as doors slamming) normally evoked a "freeze" response by the other Denver coatis. This reaction was also documented by Smith (1980) and Kaufmann (1962) when a coati had been startled by a noise. Kaufmann (1962) believed that the coatis would freeze for a few seconds in order to locate the origin of the sound. They may also freeze to avoid detection.

Scent rubbing, seen in the Denver coatis, has also been documented by Kaufmann and Kaufmann (1963) in coatis kept as pets. Just as the Denver coatis rubbed their tails and paws with catnip, the pet coatis rubbed their tails with soap (Kaufmann and Kaufmann 1963). This form of scent rubbing has not been documented in wild coatis.

Allogrooming, also seen by Smith (1980) in a captive setting, reasonably serves a function for cleanliness for the coatis. It may also serve as a foraging technique, as McClearn (1992) observed when coatis groomed nutritious ticks off tapirs (Tapirus bairdii). Russell (1981) stated that open wounds are groomed, and thus cleaned, increasing the rate of healing. Russell (1981) observed lively allogrooming between females after they had chased a male away from the band. Russell (1981) believed that the females used this type of tactile communication to "reinforce" each other's behavior. Kaufmann (1962) described mutual grooming between coatis in the field which lasted up to an hour. The longest grooming session observed in the present study was approximately ten minutes.

The brown-nosed coatis in this study exhibited foraging behaviors similar to those observed by Smith (1980). In foraging, the Denver coatis would generally walk around the enclosure singly, and become aggressive if a limited food source was investigated by another coati. If the food was abundant, such as scattered meal worms, aggression was not observed. Kaufmann (1962) stated that coatis forage together in bands, but not necessarily cooperatively. Searching for food and manipulating food items were observed regularly in the Denver coatis. The "bug-o-matic" (a cardboard tube or PVC pipe filled with crickets or mealworms) was designed by the Denver Zoo staff to enhance foraging activities. The Denver coatis exhibited a high interest in items such as mice (Mus musculus) although Kaufmann and Kaufmann (1963) alluded that captive coatis were uninterested in live prey. In Smith's (1980) ethogram of the white-nosed coati, she did not mention coprophagy, although this behavior was seen in the Denver coatis. Coprophagy has been noted in common marmosets (Callithrix jacchus) when the animals were fed diets low in protein (Flurer and Zucker 1988). The captive coatis' diets must be reviewed in order to determine if the food provided contains the protein required for maintenance.

The similarities in the foraging behaviors of the captive and wild coatis may be due to the presence of natural items in the exhibit and also the ability of live prey, such as mice and squirrels (Sciurus niger), to enter the exhibit. Foraging techniques include behaviors such as searching and object manipulation. Searching evokes alertness and exercise. Instead of simply putting food in a bowl for captive servals (Felis serval), one study found that dangling meat from ropes kept the servals more alert and induced exercise as they leapt for the meat (Markowitz and Woodworth 1978). Object manipulation is also an integral part of the foraging process, and in one study, the black bear (Ursus americanus) in captivity displayed a reduction in stereotypic pacing after logs filled with honey were introduced into the exhibit (Carlstead et al. 1991). Just as bears and servals spend a large portion of the day foraging, so does the coati, and stimulating this natural behavior may reduce captive stereotypies.

Applying behavioral research to zoo animal management is important to the health and well-being of the captive animals. It may also assist in reintroduction programs that rely on normal behavioral patterns in order for them to be successful. The animals must be able to forage successfully and find shelter. Wemmer and Derrickson (1987) compiled a list of other considerations when reintroducing a captive-held or captive-bred animal into the wild. First, the site for the reintroduction must be suitable regarding food and water resources and terrain. Due to the naiveté of the introduced animal, predation must be minimal (Wemmer and Derrickson 1987). Second, the animals must be in excellent physical condition (Wemmer and Derrickson 1987). This condition would help the reintroduced animal in foraging distances, catching prey, fleeing predators, breeding, and constructing nests or shelters. Third, an adequate number of captive animals must be reintroduced to compensate for natural losses which may deplete the breeding population (Wemmer and Derrickson 1987). Fourth, young adults should most likely be reintroduced due to their adaptability to new environments (Wemmer and Derrickson 1987). Fifth, to deter imprinting, the animals should be raised by parent-rearing techniques (Wemmer and Derrickson 1987). If possible, the animals must fear humans and learn to avoid them in the wild. It is important that a captive situation, concerned with the health of the animals, follow these conditioning programs to prepare the animals for their release into the wild.

Contact Calls

As with psychological and physical conditioning, the reintroduced animals must also be able to successfully socialize and communicate with conspecifics. Social animals that must contend with poor visibility or dense foliage may benefit from acoustic recognition such as dolphins (Sayigh et al. 1990), wolves (Tooze et al. 1990), bats (Scherrer and Wilkinson 1993) and pygmy marmosets (Snowdon and Cleveland 1980). Coatis, found in many densely vegetated habitats, would benefit from individual acoustic recognition due to the limited visibility. Coatis must maintain contact with each other if they are to continue to forage separately but travel together. Wiley and Richards (1978) stated that the structural properties of a contact call are to optimize the ability to relate information regarding the identity and location of the caller. Contact calls are a form of contact behavior involving the exchange of acoustic signals (Immelmann and Beer 1989). The chirp, which is proposed here to function as the contact call, was emitted by the Denver coatis at an average rate of 25 times a minute. I believe that this single syllable call is the contact call in this species because the coatis chirped as if to keep in touch with the others while foraging. However, when the coatis were separated from each other, they would chirp louder while running around the enclosure, even trying to reach the separated coati. Kaufmann (1962) described a "soft chitter" (several syllables in length) as the coati contact call. I believe that the chirp more closely resembles a contact call in context and in form. The chirp heard in this study is shorter in duration and would be ideal in localizing group members without alerting predators to the exact position. When a potential threat is seen/heard the Denver coatis would refrain from emitting the chirp vocalization. They would resume when the stimulus was gone or they no longer perceived it as a threat (e.g. habituation). It would be much easier for the coatis to halt a short vocalization such as the chirp than it would be to halt a chitter consisting of several syllables.

The contact calls were emitted one at a time and immediately sequential, but never overlapping. Although there was no consistent order of emission of individual contact calls, some trends existed. As stated earlier, the Denver coati "D" emitted contact calls more frequently than any of the other coatis. "D" would chirp, followed immediately by "L," and several seconds later followed by "E." "D" would then chirp again and another coati would chirp seconds later. The occurrence of these contact calls may indicate a potential social hierarchy. Kaufmann (1962) did not find evidence for a dominance hierarchy in the wild female coatis he studied. However, Gilbert (1973) noticed particular females in front and rear positions while traveling as a band and suggested that there is a element of leadership structure in the coati social system. The vocalization behaviors of the Denver coatis provide evidence that "D" may be a control animal in this captive situation and the primary focus of the band. Berstein (1966) and Wilson (1975) demonstrated that animals in captivity may not exhibit hierarchies, but rely on a control animal responsible for moderating fights, initiating defense, and may be the primary focus of attention by the other animals. Smith (1980) also observed a potential social hierarchy in the positive social interactions between the captive female coatis she studied. Smith (1980) noted that a control animal would be beneficial in the coati band while traveling and for maintaining the cohesion of a band.

The acoustic analyses also indicated that the individual Denver coatis could be identified on the basis of frequency variances in their contact calls. Each coati exhibited a distinct pattern of the contact call (Figures 1-5). Individuals differed significantly in all harmonic measurements ($p \geq 0.05$). The harmonic appeared to be the most individually distinctive feature of the contact call. These unique calls may make it possible for the coatis to recognize individuals within the related band or to detect strangers. The individual frequencies emitted with each contact call are an added social element which may allow the coatis to distinguish between band and non-band individuals. This recognition would be useful in keeping the band together and in avoiding aggressive encounters with other bands. As with the coatis, the harbour seal (Phoca vitulina) is able to recognize individuals in an area of low visibility (Hanggi and Schusterman 1994). The underwater vocalizations of the male harbour seal were found to contain individual variation similar to that of the captive coati in that the variances were revealed within the fundamental frequencies, but not in duration (Hanggi and Schusterman 1994). However, the seals' roars did not function as a contact call (they were used as a mating display) but may be used to reveal the sender's identity (Hanggi and Schusterman 1994).

Ultrasound was detected in the contact call of the captive coatis at the Denver Zoo. The frequencies registered 30-55 kHz. Ultrasound has been detected in several mammalian orders including Rodentia (Schenk 1978; Lepri et al. 1988), Cetacea and Chiroptera (Schnitzler et al. 1980) and Carnivora (Heffner and Heffner 1985). It has also been recorded in primates, in two prosimian species, the bushbaby (Galago senegalensis) and the slow loris (Nycticebus coucang) (Zimmermann 1981). Many of these animals are social and may need to keep in contact with one another without alerting predators. Pye (1979) stated that the difference between sound and ultrasound is that "air absorbs higher frequencies more than lower ones," and thus is difficult to detect from a distance. In habitats with dense vegetation, ultrasound is easily deflected within the foliage. In social interactions, usually at close distances, short-lived, high frequency vocalizations are used during contact calls between mother and infant (Galago senegalensis: Zimmermann 1981) and during sexual behavior in rodents (Microtus ochrogaster: Lepri et al. 1988; Rattus novegicus: Adler and Anisko 1979). These close-range situations require close-range vocalizations in which the sound does not travel far, and therefore ultrasound may be an ideal element of the contact call. Ultrasound use in close-range situations (such as mating and mother-infant interactions) may have evolutionary advantages in that these reproductive situations require the safety from predators. The coati reasonably uses short-duration, ultrasonic contact calls to communicate with conspecifics in their densely vegetated habitat, permitting this social animal to contact band members without alerting predators.

Communication is an important part in the sociality and survivability of an animal. Naturalistic captive settings may be able to provide the ideal situation in which animals can socialize and communicate as if in the wild. Maintaining the natural behavioral repertoire and communication abilities of zoo animals is important if we are to successfully captive-breed and/or raise and release species into the environment. Natural behaviors, including communication abilities, may make it possible for the released animal to survive longer, avoid predators, and breed successfully in the wild. Zoos, implementing modern conservation strategies, must consider behavioral diversity, including acoustic communication, to increase the survivability of reintroduced animals.

CHAPTER VI

CONCLUSIONS

1) The captive brown-nosed coati, Nasua nasua, demonstrates similar behaviors as the white-nosed coatis in captivity studied by Smith (1980) and coatis studied in the wild by Kaufmann (1962). However, behaviors documented in this study which were not noted in other studies are coprophagy, "bridging" and tail displays.

2) The contact call of the brown-nosed coati may be described as a "chirp" ranging in fundamental frequency from 5-12 kHz and in harmonic frequency from 10-18 kHz. The contact calls ranged in duration from .146-.184 seconds for the fundamental element and .09-.16 seconds for the harmonic. Contact calls were in emitted in contexts of separation from each other and while foraging and walking around the enclosure.

3) Ultrasonic frequencies in the contact call of the coati may assist this animal in communicating without alerting predators of its location. The ultrasonic frequencies ranged from 30-55 kHz.

4) The contact call of the coati reveals individual signature frequencies which may be used in individual recognition. The significantly distinct aspect of each of the animals' contact call was in the calls' harmonics.

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CURRICULUM VITA

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EDUCATION:

Year	Degree	Institution	Area of study
1990	BA	University of Northern Colorado	Zoology
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PROFESSIONAL EXPERIENCE:

Year	Location	Position	Responsibilities
1994	University of Northern Colorado	Graduate Assistant	Lab animal care
1994	University of Northern Colorado	Laboratory Technician	Research
1992-1994	University of Northern Colorado	Teaching Assistant	Teaching BIO 111
1992	Mother Earth	Pet Store Clerk	Animal care, Sales
1991-1992	West Ridge Animal Hospital	Animal Care Attendant	Pet/Wildlife care
1991	Pacific Whale Foundation	Naturalist	Research
1988-1990	Frank's Seed & Hatchery	Senior Pet Store Clerk	Animal care, Sales

RESEARCH EXPERIENCE:

Participant on NSF award: NSF Young Investigator: Impacts of disturbance on soil food webs. Department of Biology, University of Northern Colorado, Greeley, CO. $125,000 for 5 years; 1993-1994.

Participant with The Pacific Whale Foundation: Photographic identification of the humpback whale and recording of whale songs. Internship, Maui, HI; 1989.

Participant with The Pacific Whale Foundation: Survey of the human/vessel impact on the humpback whale. Maui, HI; 1991.

PROFESSIONAL PRESENTATIONS AND ABSTRACTS:

Trudgian, M.A.; Clarke, J.A.; Ackley, S. 1994. Acoustic communication and the use of ultrasound by coatis (Nasua nasua). Thirty-first Annual Meeting of the Animal Behaviour Society. University of Washington, Seattle, WA.

Trudgian, M.A.; Clarke, J.A.; Ackley, S. 1995. Acoustic communication and the use of ultrasound by coatis (Nasua nasua). Second Annual University of Northern Colorado Research Symposium, Greeley, CO.

Trudgian, M.A. 1995. A study of the captive brown-nosed coati (Nasua nasua): An ethogram and contact call analysis. Sigma Xi, University of Northern Colorado, invited speaker.

AWARDS AND GRANTS:

1993	A study of the captive brown-nosed coati (Nasua nasua): An ethogram and contact call analysis. Sigma Xi Research Grant, University of Northern Colorado, Greeley, Colorado. $150
1995	Acoustic communication and the use of ultrasound by coatis (Nasua nasua). First Annual Outstanding Student Paper Award, Graduate Research Network. Second Annual University of Northern Colorado Research Symposium, Greeley, CO. $300

PUBLICATIONS IN PREP:

Trudgian, M.A.; Clarke, J.A.; Ackley, R.S. Signature frequencies in the contact calls of the brown-nosed coati (Nasua nasua). In prep for Animal Behaviour.

REFERENCES AVAILABLE UPON REQUEST