AN ABSTRACT OF THE THESIS OF

Ramesh S. Krishnamurthy for the degree of Master of Arts in Interdisciplinary studies in Anthropology, Wildlife and General Science presented on December 4, 1991. Title: Vocalization Patterns of Captive François' Langurs (*Presbytis francoisi*).

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Abstract approved __

Roberta Hall

Vocalization patterns of two groups of captive François' langurs (*Presbytis francoisi*) were studied between August 1989 and June 1990. During the 11 months of observation, 109 hours of vocalization recordings were made at Metro Washington Park Zoo, Portland, and the San Diego Zoo, San Diego. Based on the behavioral observations and the vocalization recordings, two categories of vocalization types are described. Type I consists of 20 basic patterns including infant vocalizations and a vocalization recorded by other observers. Type II consists of 3 patterns related to stereotypic behavior and possible stress under captive conditions. Physical characteristics and the context of behavior for each call type are described. Spectrograms are given for all call types except the loud call. Among the calls recorded, whistle vocalizations of infants are the longest in duration.

Comparison of vocalization patterns of *P. francoisi* to those of other species of the genus *Presbytis* revealed similarities in behavior and context among some call types in the species of *P. entellus* and *P. johnii*.

VOCALIZATION PATTERNS OF CAPTIVE FRANÇOIS' LANGURS (*Presbytis francoisi*)

by

Ramesh Krishnamurthy

A THESIS
submitted to
Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Arts in Interdisciplinary Studies

Completed December 4, 1991
Commencement June 1992

Approved:

Redacted for Privacy

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ACKNOWLEDGEMENTS

I am greatful for the guidance and support of Drs. Courtland Smith, John Lyford, Bruce Coblentz and Katharine Field. My special thanks go to Prof. Roberta Hall, who, in addition to providing direction, spent many hours carefully reading and rereading this script, and to Dr. Paul Simonds of University of Oregon, Eugene, for giving me guidance, suggestions and support throughout the project. I am also greatful to Dr. Jill Mellen, Mr. Dave Thomas and Mr. Mike Marshall, for allowing me to conduct research at the Metro Washington Park Zoo, Portland, and to Ms. Karen Killmar, Ms. Dean Gibbson, Ms. Elaine Chu and Mr. Jim Maxwell, and other primate keepers of the San Diego Zoo, San Diego. My sincere appreciation and thanks also to the Department of Anthropology, for providing office space, Clifford Mead of Special Collections, Kerr Library, for loaning the camcorder and providing office space, Charles Meslow at the Fisheries and Wildlife Department for loaning me a tape recorder, Mrs. Judith St John and Mr. Mark Reed for their help in editing the video tape, and Drs. Michael Beecher, Eliot Bronovch and Mr. John Burt of the University of Washington, Seattle, for their help and assistance in obtaining spectrograms.

Finally, I would like to express my deep appreciation to my beloved wife, Gowri Ramanathan and to my parents, whose encouragement and support made this endeavor a reality.

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CAPTIVE FRANÇOIS' LANGUR (*Presbytis francoisi*)

1. INTRODUCTION

Order Primates: An Overview

In the 18th century, Carl Von Linnaeus, the founder of modern systematics, placed the Order Primates at the top of the animal kingdom. He listed 25 species of primates in his book *Systema Naturae*, published in 1758. In the twentieth century, primatologists around the world added new species to the Linnaean list of primates and the field of primatology has grown both broad and specialized. It is estimated that there are more than 500 extant species and subspecies of primates (Kuhn 1989) both from the Old World and the New World, and the list is being continuously enlarged. Recent additions include a new species of *Propithecus* from Madagascar, (Simons 1988), and rediscovery of *Allocebus trichotis*, the hairy-eared dwarf lemur, in some parts of Madagascar (Meier and Albignac 1991).

Variation in body size among primates is very noticeable. The smallest living primate is the mouse lemur, *Microcebus murinus*, which is endemic to Madagascar and which weighs only a few grams. The largest living primate, *Gorilla gorilla*, may weighs over 800 kilograms. Among the most colorful primates are the Douc langurs, *Pygathrix nemaeus*, considered to be the most strikingly colored of all mammals. All three of these species are listed as endangered.

The utilization of non-human primates varies to a considerable extant. They are used as pets, as food, in biomedical research, and in some countries macaques have been used to pluck coconuts from the trees. In a few parts of Asia, some species of langurs and macaques are considered as sacred animals.

Classification

The order is classified into two sub-orders: (a) Prosimii, which includes Daubentoniidae, Cheirogaleidae, Indriidae, Lemuridae, Lepilemuridae, Lorisidae, and Tarsiodiae, and (b) Anthropoidea, comprised of Callimiconidae, Callitrichidae, Cebidae, Cercopithecidae, Hylobatidae, Pongidae and Hominidae (Smuts et al. 1987). A detailed description of the classification is given in Figure 1.

General Characteristics

In non-human primates, the first digit of the hind foot is opposable, and usually the thumb is also opposable. Most primates have five digits on each limb. A tail is absent in Hominidae, Pongidae, and Hylobatidae, and a few species of other families. Among other characters, primates possess greatly developed cerebral hemispheres. This feature is pronounced in the genus *Homo*. Most primates have short noses, with the sense of smell being secondary to the senses of vision, touch, and hearing. The eyes generally face more forward than laterally, and thereby facilitate true stereoscopic vision.

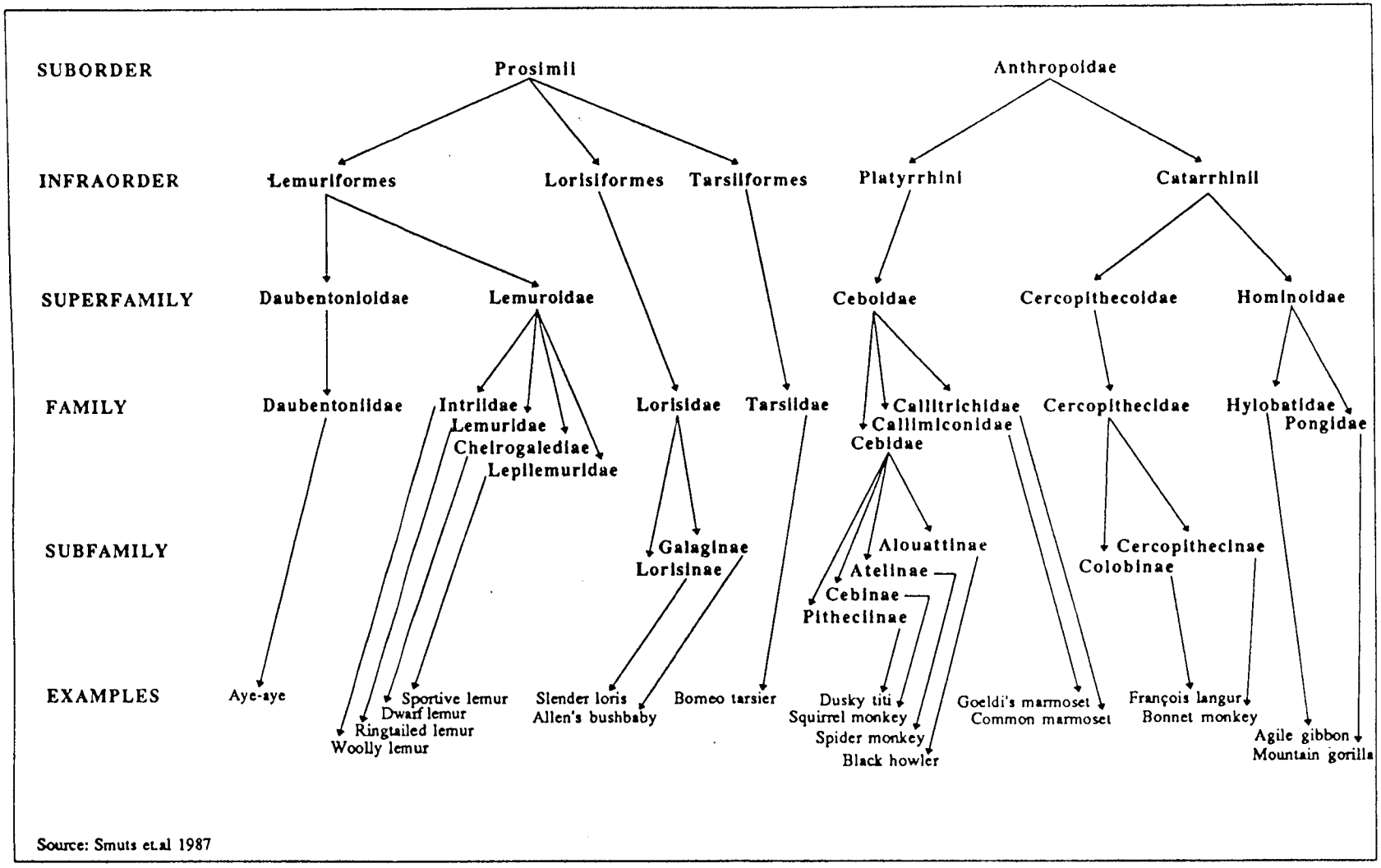

Figure 1 Classification of Extant Non-Human Primates of the World

Distribution

The present distribution of non-human primates is confined to the tropical and subtropical regions of both the Old and the New World, roughly between 40^0N and 40^0S latitudes. The primary areas include Africa, the island of Madagascar, the Indian sub-continent, south-east Asia and South and Central America (Figure 2). There are no indigenous primates in North America, Australia or Europe.

Africa is home to a large portion of extant species of primates. The island of Madagascar harbors one of the most interesting groups of primates - lemurs, which are endemic to the region. In South and Central America, many species of Cebidae and Callitrichidae are found in Amazonian rainforests. Asia is inhabited by several families of primate including lesser and greater apes.

Ecology

The habitats of living primates range from almost exclusively arboreal to terrestrial, with many species in between. They occupy a wide range of habitats. The varied distribution includes desert to snow conditions, rainforests to grasslands. The tropical forests of South America, Africa and South East Asia harbor many primate species. The lemurs and lorises are considered to be primarily arboreal. Some other species of monkeys and apes live in the upper canopy of the forest and are seldom seen on the ground. The preference for a particular canopy level varies across species. On the other hand, some species such as bonnet macaques spend considerable amounts of time on the ground

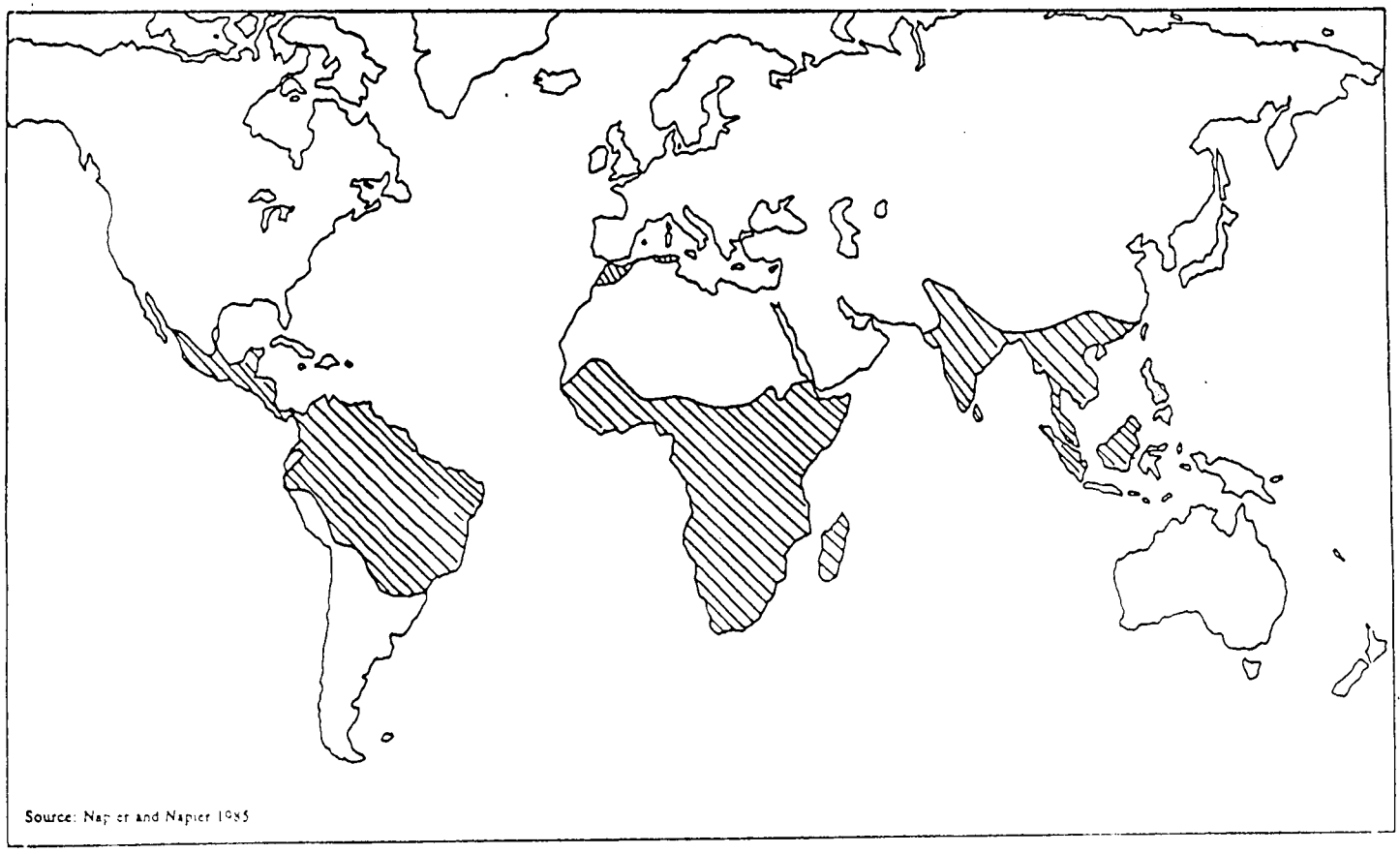

Figure 2 Distribution of Extant Non-human Primates of the World

during feeding. Primates are not found in the rainforests of New Guinea and northeastern Australia, which lie east of the Wallace's line (Napier and Napier 1985).

The diversity of primates varies considerably from one rainforest to another. New World rain forests contain more species than any other region in the world, with as many as 22 (or more) in just 500 square kilometers in Upper Amazonia (Hershkovitz 1970; Mittermeier and Coimbra-Filho 1977). In seasonal forests including monsoon forests, such as the forests of western Thailand, species of apes and monkeys can be found. The woodland and shrubland vegetation in Madagascar harbors lemuroid species such as *Microcebus* sp. In the African savannas are found species such as baboons (*Papio* sp.), patas monkeys (*Erythrocebus patas*), and chimpanzees (*Pan troglodytes*). In temperate vegetation types of Asia, Old World monkeys like rhesus macaques (*Macaca mulatta*), golden or snub-nosed monkeys (*Rhinopithecus roxellanae*) and langurs (*Presbytis* sp.) can be seen.

Many species of Cercopithecinae (e.g., macaques), and Colobinae (e.g., langurs), live in mixed deciduous and needle-leaved evergreen forests of south and southeast Asia. Some macaque species, including the Japanese snow monkey (*Macaca fuscata*), which lives in mountains of Japan, and the barbary macaque (*Macaca sylvanus*), which lives in the Atlas Mountains in Morocco, have adapted well to severe weather conditions. As winter approaches they grow a heavy

insulative coat. They also change their behavior to adjust to different weather conditions.

The diet of primates varies by species. Some are insectivorous. Others are carnivorous and may feed on crabs, mollusks, birds and birds' eggs; some such as baboons and chimpanzees have been observed feeding on small gazelles. More common foods are fruits, seeds, flowers, leaves, latex, sap and gum, woody stems and underground plant parts. The majority of primates drink water and some get water through feeding on succulent leaves and insects. Diet depends on the seasonal availability of food and the pattern of selection may vary by species. Under captive conditions, primates readily adapt to raw as well as cooked foods and artificial diet such as milk, bread and vitamin biscuits (Roonwal and Mohnot 1977).

Sociobiology and Behavior

Primates, in general, are social animals, although individuals of some species spend much of their lives entirely alone. The social organization has been categorized in six different classes (Roonwal and Mohnot 1977): solitary (e.g., lorises), mated pair with offspring (e.g., indris, galagos and gibbons), group with only one male (e.g., patas monkeys and the hamadryas baboon), group generally oriented to one male (e.g., some langurs), group with multiple adults of both sexes (e.g., some lemurs and howler monkeys) and unstructured aggregation (e.g., galagos, geladas and several species of baboons). Group composition varies

according to the social structure. In multi-male groups, (e.g., ring-tailed lemur, mantled howler and Rhesus macaque), the group consists of several adult males, several adult females, and their offspring. In uni-male groups (e.g., hanuman langurs, hamadryas baboon and guenon), the composition includes a single adult male, several adult females and their young ones. Some primates exhibit family groups which resemble the human nuclear family structures (e.g., white-handed gibbon).

Primates are involved in a wide range of behavioral patterns. They include grooming, agonistic interactions, play, mating and feeding. Other forms of behavior seen among primates include infanticide and cannibalism. Many species of primates exhibit a remarkable hierarchy among groups. In a uni-male group of *Presbytis entellus*, dominance will be attained by the single adult male present in the group. However, in the case of multi-male groups, dominance may be attained by competition, occasionally including severe aggression that sometimes is fatal (Roonwal and Mohnot 1977).

Sexual Behavior

Primates have adopted various forms of social grouping that enable males and females to mate and reproduce. In female non-human primates, oestrus is for a limited period of time. During this time, females will be mated by the dominant male(s) of the group. In group-living primates such as bonnet macaques, the male and female separate soon after copulation. Dominance plays an important role in

the reproductive behavior of individuals within a group. Males which are denied access (by other males) to receptive females may lose rank or may become outcasts. Since dominance, large size, and aggression are often positively correlated (Trivers 1972: 160), these factors play a role in reproductive success. Parental care among primates varies across the order.

Study of Primate Vocal Communications

The study of primate vocal communications is of interest because of its presumed similar origins to human vocal communication. Among primates, communication between individuals is also achieved by visual, olfactory and tactile means. For the past two decades primate vocalization has been studied by many researchers. Early studies by Altmann (1967) and Rowell and Hinde (1962) have increased the understanding of primate vocal behavior. However, vocalizations of only a few species have been well documented.

Vocal communication in primates plays an important role in all aspects of social structure. Vocalization is also an important form of communication in almost every aspect of social behavior.

There are several reasons to study vocalizations among primates. The following list indicates things we can achieve by understanding vocal communications among primates:

a. "The Order Primates is an order that is quite susceptible to massive extinction. It is critical that we develop an understanding of

communication in many primate species both to obtain a record of the biological variability represented by primate species that may not be with us in another few decades and to be able to make intelligent decisions about the size and location of islands or reserves to be preserved" (Snowdon et al. 1982; XVII).

b. Knowing how far "long calls" travel and how they function will help us determine how large home ranges must be for different species and thus how many groups could be kept in a given reserve.

c. Understanding communication involving sexual signaling can be of immense value in attempting to preserve endangered species in captivity, and in reintroducing them to their natural habitats.

d. Understanding the role of vocal communication in developing and maintaining group cohesion and relationships between individual animals can help us evaluate whether a given aggregation is going to function successfully as a breeding population.

e. As vocal communication plays an important role in social behavior, understanding of vocal communication is a necessary prerequisite to the understanding of any species' social behavior. Primate play vocalizations, such as maternal retrieval of infants (Masataka et al. 1988), have some functional significance. This information on mother-infant relations will be of immense value when animals are transferred from enclosure to enclosure or from Zoo to Zoo.

f. Vocal repertoire can be used in comparing subspecies (Zimmermann et al. 1988), and perhaps even local populations. Vocal recordings can also be used to verify hybridization among species as demonstrated by Hohmann (1988).

g. The comparative studies of different species of the same genus can lead to hypotheses and conclusions regarding the ancestral calls (Mori 1983) and phylogeny.

h. Studies of vocalization yield functional and evolutionary implications of behavior among many primates.

i. Among higher primates, the phonological analysis of certain songs (e.g., gibbons) may help us understand human linguistic structure.

The study of vocal communication involves a series of steps. The primary step is the preliminary observation of the animal in its natural habitat or under captive conditions. Field studies involve detailed observations of individuals of a species for a considerable period of time. The next step is the observation and collection of data based on the objectives of the researcher. Behavioral parameters are recorded to correlate behavior with corresponding vocalizations. In the field, data can be collected on group activity, direction of group movement and details on vocalization such as the form of vocalization, spatial distribution of vocal emitter, age and sex of emitters and context of emitting. The duration and the observation depends on the objectives of the researcher. Recordings of vocalizations may be

made on audio and/or video tapes. The spectrographic analysis of vocalizations and the interpretation of the collected data give a broad picture of the different aspects of vocalization patterns.

A study of vocalization both in captive populations and in the field can be a valuable source of behavioral information. Studies of both captive and wild populations have their positive and negative aspects. Observation of captive populations may answer specific questions that are difficult to address from the field. Most captive primates are tuned to the environment they live in, however; this will usually bias the results if generalities are based only on captive studies.

Although field work plays a vital role in collecting information on specific aspects of communication, captive primates can yield considerable data for analysis. For instance, vocalization recordings of females during pregnancy are difficult to achieve in the wild, but can be recorded fairly simply in captivity, as demonstrated by Hammerschmidt and Ansorge (1989). Similar recordings such as vocalizations involving nocturnal primates are much more difficult to achieve in the field. Vocal behaviors of rare species can also be more easily studied in captivity than in the wild. Playback of a vocalization with specific behavioral patterns, such as facial expressions, can be better examined under captive conditions than in the wild due to problems with visibility. Behavioral comparisons of different species for a particular call type can be more easily made in a captive condition and may be more economically feasible than in field settings. Recording calls involving ultrasonic frequencies can be done by isolating primates in special enclosures and

monitoring them. Such recordings are often difficult to obtain from the field, and the source of any ultrasonic vocalizations difficult to identify with certainty. Unmonitored vocal recordings can be more easily achieved than in the wild. Calls such as stereotypic and stress induced calls can only be recorded under captive conditions, as in the wild such calls are often not found. One drawback of captive studies is that they may produce an incomplete documentation of vocalization of any species.

In some species of primates, loud calls will have a functional significance in maintaining inter-male distances (Tenaza 1989). To observe and to study these, field study is a must. Monogamous primates maintain exclusive use of their ranges by regularly establishing and reinforcing the conventional location of boundaries (Robinsion 1981). Data on specific alarm calls and warning calls can be collected more accurately from field studies than from captivity.

Summary

There are approximately 500 species and subspecies of extant primates distributed in the tropical and subtropical regions of both Old and New World. The majority of the species live in social groups while some are solitary; all exhibit a wide range of behaviors. Communication between individuals is achieved by various means. Among those, vocal communications play an important role in all aspects of primate social structure. The study of behavioral context is an important component in studying vocalization patterns of a given species. There are both

positive and negative aspects to collecting data on vocalization in both captivity and field conditions.

2. STUDY AND METHODOLOGY

Presbytis francoisi

Cercopithecidae, the largest family among primates, is comprised of two subfamilies: Cercopithecinae, which includes macaques, and Colobinae, which includes the genus *Presbytis*, also known as langurs. "Langurs have slender bodies, long tails, and long, slender hands. The thumb is small, but the other fingers are well developed and strong" (Walker 1964; p. 463). In general, langurs are diurnal, arboreal forest dwellers (Roonwal and Mohnot 1977; Medway 1970). They are best known for their peculiar digestive anatomy and physiology. In the large, four-chambered stomach the frontal portion is less acidic than the distal portion. The higher pH (5 to 7) in the stomach enables anaerobic fermentation with the help of cellulytic bacteria (Bauchop 1971). The polygastric condition of the stomach distinguishes the subfamily Colobinae from all other primates who have monogastric stomachs. This digestion allows the colobines to exploit a diet of leaves generally unavailable to other primates, and may also reduce their requirements for water.

The genus *Presbytis* is endemic to Asia. This genus is widely distributed from Kashmir and Nepal through Burma and China, and southward through the Indian subcontinent, Indo-China and Malaya to Sumatra, Java and Borneo (Figure 3). They occupy a wide ecological range, including the dry zones of India and Sri

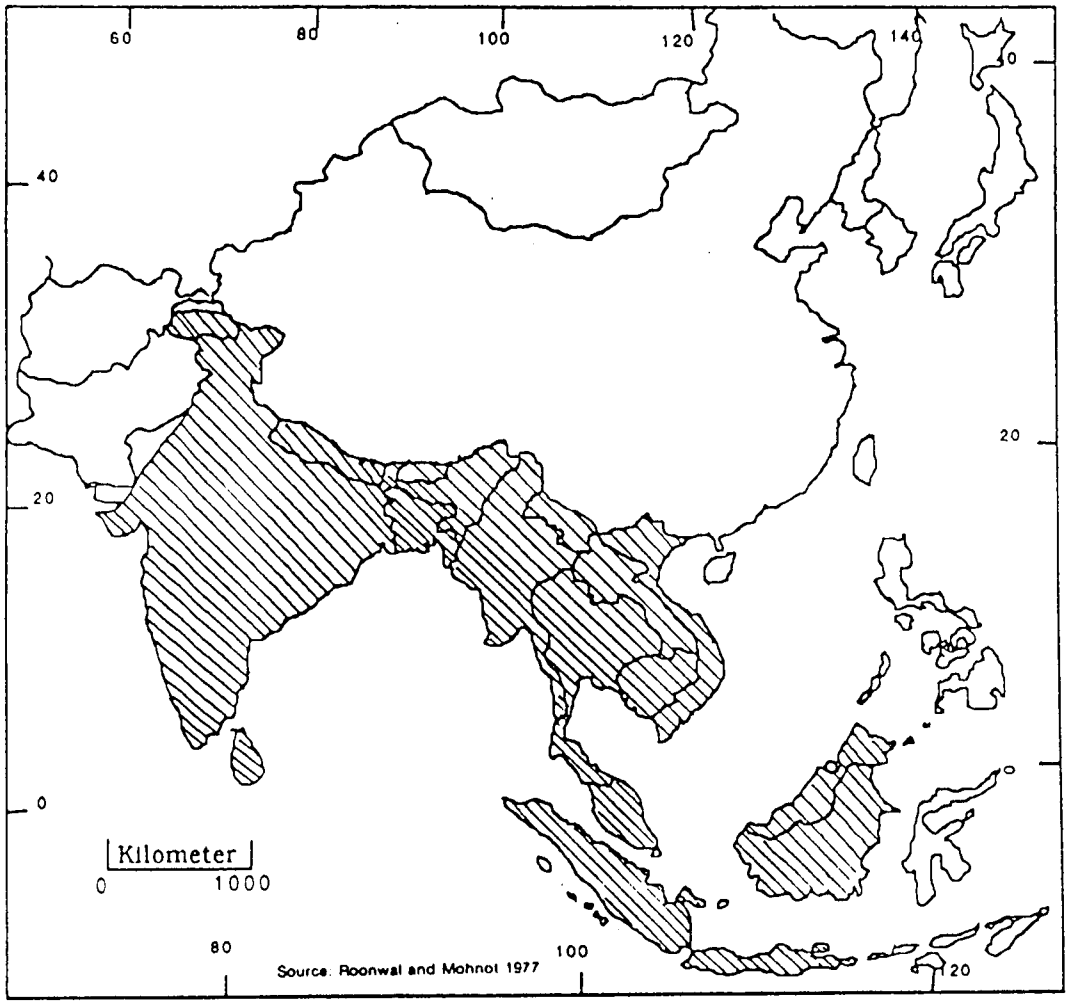

Figure 3 Distribution of genus *Presbytis*

Lanka, snow-covered habitats and rocky outcrops in the Himalayas, mangrove swamps and rain forests.

Presbytis francoisi

Presbytis francoisi, also known as François' Schlankaffe, François' langurs and the Tonkin leaf monkey, belongs to the subfamily Colobinae. The species is found in the rocky areas of southeast Asia from southeastern China to central Laos and Vietnam (Wolfheim 1983; MacKinnon and MacKinnon 1987). Its northernmost record is in Kwangsi, China at 22°35′N. and 107°57′E., and its southernmost locality is Quang at 17°50′N, 106°00′E in central Vietnam (Fooden 1976). A detailed map is given in Figure 4.

Six subspecies of François' langurs are recognized (Ma, et al. 1989): *P. f. delacouri*, *P. f. francoisi*, *P. f. hatinhensis*, *P. f. poliocephalus*, *P. f. laotum* and *P. f. leucocephalus* (Table 1). All subspecies are crested and mainly black in color, and have varying amounts of white or gold on the head, body and tail. Sexual dimorphism is absent among *Presbytis francoisi*. The young are orange in color until they reach 3-4 months of age (Figure 5). According to the zookeepers at the San Diego Zoo, the transition from orange to black occurs around four months of age. Individual variation during transition has been observed and in some cases the retention of halo-brown color has been observed in one year old males. A detailed description of the hair coloration is given in Table 2.

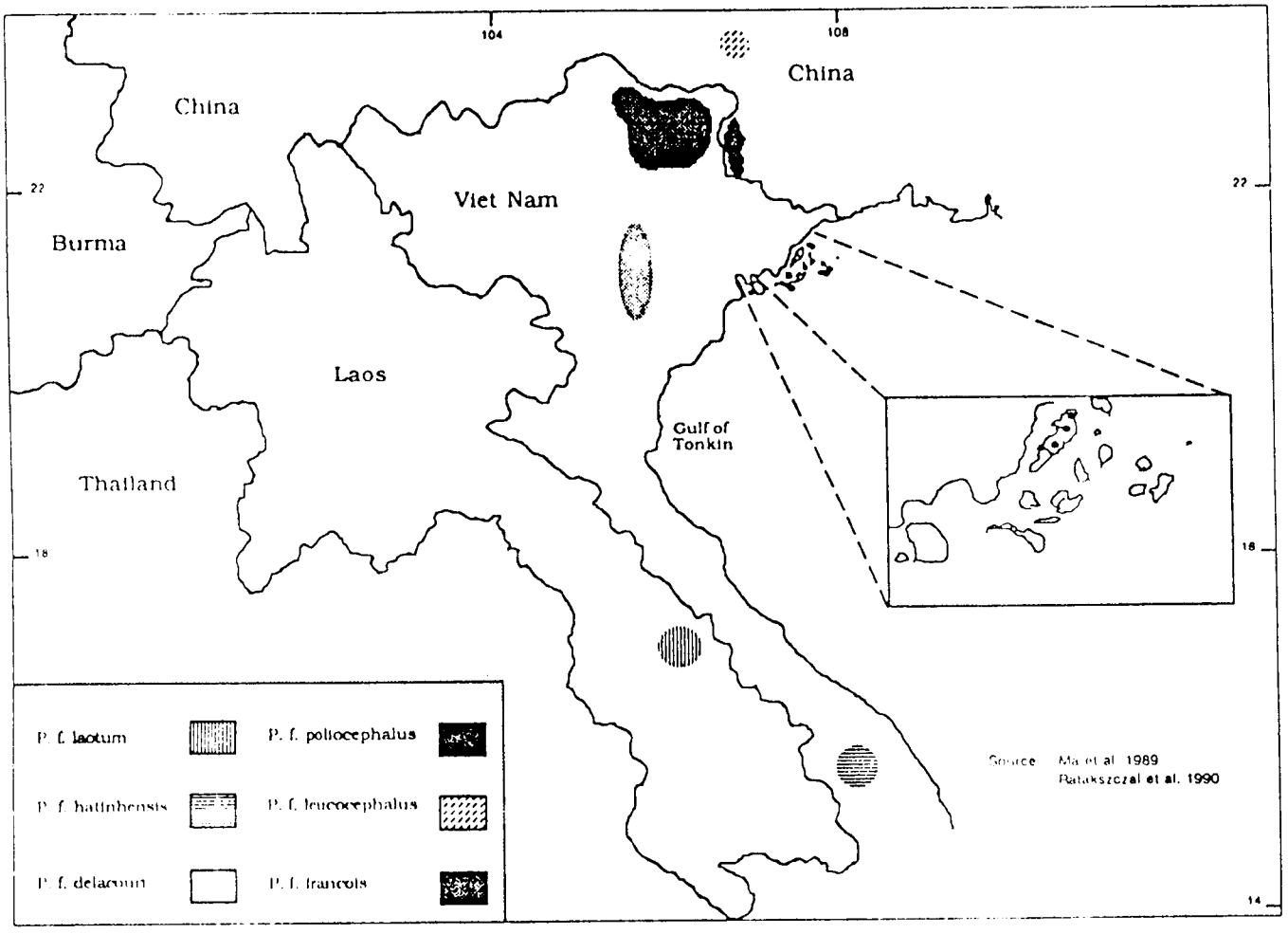

Figure 4 Distribution of François' langur (*Presbytis francoisi*)

Table 1 Distribution of *Presbytis francoisi*

SUB SPECIES	DISTRIBUTION RANGE
P. f. delacouri	Cuc Phuong National Park, Karst limestone hills, northwest of Cuc Phoung National Park, Thuong Xuzn and Quan Hoa districts[1], Thann Hoa Province, Hol Xuzn, Northeastern Vietnam[2].
P. f. francoisi	Ba be National Park (Cho Ra district, Cao Bang province), Ra Ban village[1], Longzhou, Guangxi province, southern China, and along the border area of northern Vietnam[2].
P. f. hatinhensis	Xom Cuc in north-central Vietnam (17°55′N 105°48′E)[1].
P. f. poliocephalus	Cat Ba island (south east of Cai Chien)[1]. Kai-Chin, Tonkin, northeastern Vietnam[2].
P. f. laotum	Eastern bank of the Mekong river in Laos, Ban Na Sao (17°30′), Southern Laos[2].
P. f. leucocephalus	Narrow area along the southern Zuo river and along the eastern Ming river in southern Guangxi (Wu et.al. 1987), Sangen Mountain, Chougzuo county, southern Guangxi province, China.

[1] Ratajszczak et.al 1990

[2] Ma et.al 1989

Table 2 Hair coloration of six subspecies of *Presbytis françoisi*

Subspecies	Head	Crest	Cheeks	Behind	Neck ears	Rump, thighs	Tail	Limbs
P. f. francoisi	Black	Black	Pure white	Black	Black	Black	Black	Black
P. f. poliocephalus	Flavous and white around the face	Golden yellow	Yellow or off white	Bluish black	Golden yellow	White or buff	Black mingled white	Black
P. f. laotum	White	Deep black	White scattered black	White	White, black on nape	Pure black	Black	Black
P. f. delacouri	Black	Black	Grayish white line	White patch	Brownish	Pure creamy white	Glossy black	Glossy black
P. f. leucocephalus	White	White or black on the tip	White	White	Pure white	Grayish black with white patch	White, pure black at base	Gray black-or with white
P. f. hatinhensis	Black	Black	Grayish white line	Larger white patch	Black	Black	Pure black	Black

Source: Ma et.al. 1989

Little or no information is available on territoriality and home range of this species. The information on social behavior and breeding season is scanty. The species is classified as endangered under the U.S. Fish and Wildlife system (U.S. Department of Interior 1977).

Objectives

The main purpose of the study was to investigate the audiosonic vocalization patterns associated with behavior among captive François' langurs. The objectives of the research were:

a. to record and categorize the vocalization patterns

b. to record the behavioral context in relation to the occurrence of vocalization.

c. to classify vocalizations according to age and sex.

Study sites

Between August 1989 and June 1990, two groups of captive François' langurs were observed at the Metro Washington Park Zoo, Portland, Oregon (Figure 9) and San Diego Zoo, San Diego, California (Figure 8). Over a period of 11 months, 109 hours of vocalization recordings and the behavioral context of vocal emission were made.

The age classification of the animals at the Metro Washington Park Zoo and the San Diego Zoo was obtained from the respective Zoo records. At the beginning of the study, the group composition of the Metro Washington Park Zoo

Figure 5 Mother and Infant, San Diego Zoo

Figure 6 Two adult females sitting with vitamin biscuits on the ground, San Diego Zoo

consisted of three individuals (two adult females and an adult male). During the study, an adult female died (Table 3). Due to this, a major part of the vocalization recordings was made at the San Diego Zoo.

The group composition at the San Diego Zoo was changed during the course of observations (Table 3). Also, during August 1990, an adult female and her infant were transferred to a different Zoo, reducing the total number of individuals to 12. During the course of study, animals were moved from an indoor glass enclosure to a wire meshed open enclosure. Data on behavior and vocalization were collected at both the enclosures.

In captivity, the diet includes fruits, vegetables, eggs and nutritious biscuits (Figure 6). Feeding started around 11:30 AM in San Diego Zoo and sometimes lasted until 1:30 PM at the Metro Washington Park Zoo. At San Diego Zoo, the daily food was spread inside the "bedroom" of the langurs, to facilitate a close inspection of the health and physical condition of individuals (Figure 7). During daily food preparation, most of the individuals watched the zookeeper mixing different fruits and vegetables. The vocalizations heard during such occasions include squeals and whoop calls. Individual preferences during food selections have been observed among all age groups.

According to the zookeepers at San Diego Zoo, on most occasions during feeding, the dominant male arrived first to select food while others stayed away. An adult female with an infant waited for a few minutes before entering the feeding area. Apart from the food given, the individuals were also seen eating

Table 3 Group Composition of *Presbytis françoisi* Samples

Sex	Adult	Subadult	Juvenile	Infant	Total
San Diego Zoo [1]					
Male	1	2	0	1	4
Female	4	3	1	2	10
Metro Washington Park Zoo					
Male	1	0	0	0	1
Female	2	0	0	0	2

[1] Total number of individuals during December 1989 was 14; during August 1990, 1 adult female and an infant male were moved to Riverside Zoo, South Carolina, which reduced the total number to 12.

[2] During the study, one of the females died due to disease

Figure 7 Zookeeper feeding the François' langurs in their bedroom

Figure 8 Study site, San Diego Zoo

cockroaches, ants, and in some cases were seen peeling and eating small pieces of wall paint.

Play occurred among all age groups. Subadult play involved walking with their eyes closed, somersault, chase, tail pulling and wrestling. A mother and her newborn infant did not engage in play during the infant's first few days. Allomothering was observed during the first five days after the infant's birth. Among other tactile communications observed, autogrooming, social grooming, mouth-to-mouth contact and genital inspections were present. According to the zookeepers at the San Diego Zoo, infanticide in captivity has not been recorded in this species.

Enclosure

Metro Washington Park Zoo: The exhibit was 7.2 meters long, 3.6 meters wide and 5.4 meters in height (Figure 9). The holding areas were divided into three sections (Figure 10). The first holding area was 4.2 meters long, 1.2 meters wide and 1.05 meters high, the second area was 1.5 meters long, 1.2 meters wide and 1.6 meters high and the third unit was 6 meters long, 1.2 meters wide and 1.05 meters high.

San Diego Zoo: During the early part of observations, animals were housed in a see-through glass enclosure. The dimensions were 17.7 meters long, 5.7 meters wide and 5.7 meters in height. During the later part of the study, the langurs were moved to an outdoor wire-mesh exhibit measuring 11.1 meters long, 6.6 meters wide with an average height of 9 meters (Figure 8). The bedroom or

Figure 9 Study site, Metro Washington Park Zoo, Portland

Figure 10 Holding area, Washington Park Zoo

Figure 11 Equipments used during the study

holding area was 3.9 meters long, 2.85 meters wide and 2.25 meters in height (Figure 7).

Recordings

Data collection at the Metro Washington Park Zoo was restricted to the hours of 1000 - 1500 hrs, the period of routine maintenance. On the other hand, San Diego Zoo permitted me to record from 0645 hrs until dusk.

The distance between myself and the animals varied from less than 1 meter to a maximum of 30 meters in the San Diego Zoo. On certain occasions, binoculars were used to observe behavior in detail. Audio recording of vocalizations was stopped while monkeys were sleeping and was resumed as soon as any one of the individuals woke up. Video recordings, however, were continuously made during the time of observation.

Vocalizations were recorded on magnetic tapes using a Uher 4000 Reporter-L (speed 19 cm/s) reel-to-reel audio recorder and Marantz stereo cassette recorder (Model PMD 430) with a Calrad (super cardioid shotgun) unidirectional microphone (dynamic range:10-15,000 Hz). Behavioral data associated with the vocalization was collected by direct observation and with a video camcorder (Panasonic VHS reporter, model AG 160). The tape counter number during the occurrence of vocalization was recorded separately. A schematic representation of the equipment used during the study is given in Figure 12 (also see Figures 11 and 13). On certain occasions, verbal description of the behavior in the context of vocalizations was directly recorded on to the audio tape,

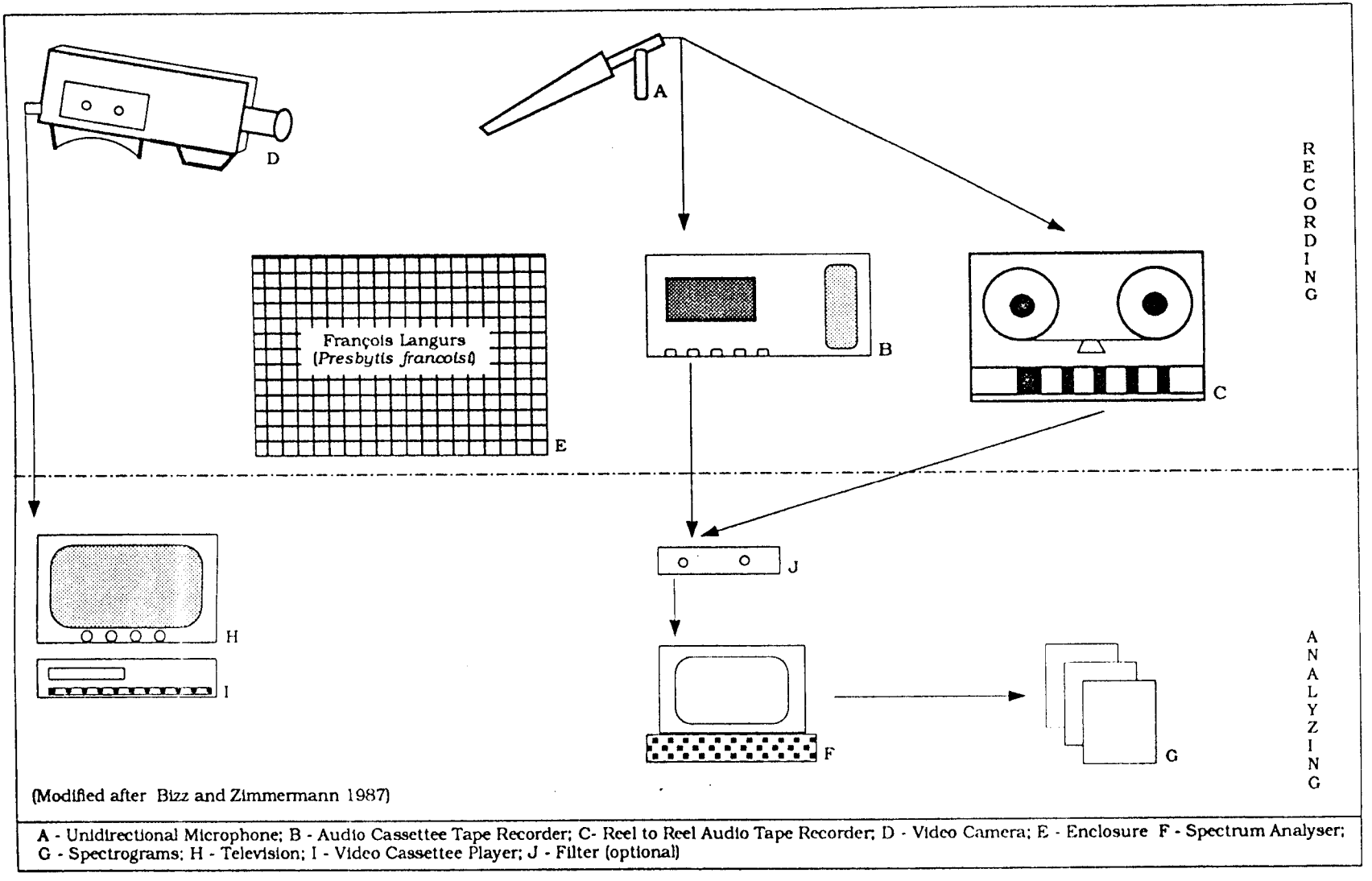

Figure 12 Schematic representation of the equipment used for recording and analysing vocalizations

Figure 13 The small rhombus shaped opening was used for recording and the large square see-through glass was used for observation.

Figure 14 Sound spectrum analyzer

as it was difficult to document on paper. However, hand notes were also obtained for most call types.

The total number of occurrences of each vocalization type was counted during replays of both audio and video tapes to obtain the total number of individual vocalization types. Individual samples of vocalization which were acoustically clear were then analyzed by spectrogram.

There were eight hours during which neither behavior nor vocal recordings were monitored, although both the video camera and the audio recorder were recording. Additionally, on certain occasions, I could not record vocalizations due to various conditions of extraneous noise (such as the noise caused by the ground maintenance personnel, rain, visitors, vocalizations of other animals such as house sparrow and other zoo animals, echoes created by the metal enclosures, and feedback of the microphone). During such conditions, only the description of the call and related behavioral observations was recorded. Certain vocalizations that I did not record, together with their behavioral context, are documented as described by the zookeepers.

Behavioral and vocal interaction of François' langurs with the other primates in neighboring enclosures, such as Douc langurs (*Presbytis nemaeus*) at the San Diego Zoo and Hanuman langurs (*Presbytis entellus*) at the Metro Washington Park Zoo, were also recorded.

Analysis

Vocalizations were sequentially located on the tape by the corresponding tape counter numbers and the description of the call. A preliminary sample of different vocalization types was then developed during the playing of the recorded tapes. Later, the vocalizations were impressionistically found on the tapes and verified and matched to the preliminary sample by listening and comparing them to spectrograms and to the behavioral context. Classification of the vocal repertoire was based on the spectrographic analysis, the context of emission and age and sex of emitter. Individual vocalization types were then developed and named according to the sound of the vocalization and/or behavior associated with the call. Names for certain call types (such as Loud calls, Whoop, Scream and Alarm) were chosen from Hohmann (1989a), as such calls are common among the genus *Presbytis*.

Calls originating from the infant were classified under a separate category, as such calls were not uttered by any other individuals of the group. The names of the infant vocalizations were based on the sound of the vocalization and the context of emission.

A separate category was made to include the possible stress induced and stereotypic vocalizations (PSV) and they are numbered as PSV 1, PSV 2 and PSV 3.

Spectrographic analysis of the vocalizations were made on a Kay Elemetrics DSP Sona-Graph Model 5500 (Figure 14). A 1.5 kHz filter was used to eliminate the

background noise of some vocal sounds. Spectrograms of vocalizations with high background noise whose frequency was below 1.5 kHz could not be obtained. A sample spectrogram was obtained for each category of call type except for the loud calls. Spectrograms for non-vocal sounds are not presented. The average bandwidth and the duration of individual vocalization types are calculated by five spectrographic samples, where available. Description of the physical structure of the calls such as low, moderate and high frequency are referred to as those frequencies between 0-4 kHz, 5-9 kHz, and 10 kHz and above, respectively. The duration of the frequencies given for spectrograms are close approximations. For each call type, the physical description of the call is given at the beginning followed by the behavioral context of the occurrence. A brief description of the terminology used in the text is given in Appendix A.

Summary

Between August 1989 and June 1990 two groups of captive François' langurs (*Presbytis francoisi*), consisting of all age groups, were observed to study the vocalization patterns. A total of 109 hours of vocalization recordings were made on both audio and video tapes. The vocalizations were then analyzed using a spectrum analyzer. Based on the behavioral and spectrographic analysis, calls were then categorized and spectrograms were obtained for each category of vocalization except for Loud call. Behavioral and vocal interactions of *P. francoisi* with primates at the neighboring enclosures were also observed.

3. RESULTS

I classified vocalization patterns of captive François' langurs *Presbytis francoisi*, into two main groups, based on the behavioral context and spectrographic analysis. Type I vocalizations were uttered during the normal daily activity pattern of langurs. The category consisted of 20 different patterns of calls that included the vocalization of infants and the vocalizations heard by other observers. Type II vocalizations were associated with stereotypic behavior and possible stress in captivity. Three different patterns of vocalization are described under this category. Spectrograms are given for all the call types except loud calls. Non-vocal sounds are described under a separate category.

A summary of call types, context of the vocalization, sex and age category of the emitter, duration and the frequency of the call are given in Table 4.

Type I Vocalizations

Alarm call

The alarm call was a short duration, low frequency tonal unit, uttered singly. The call began with a higher frequency and tapered during the middle. The energy concentration is present at the beginning of the vocalization. The duration of the call was 0.325 seconds and the total frequency range was between 1.5 to 1.75 kHz (Figure 15).

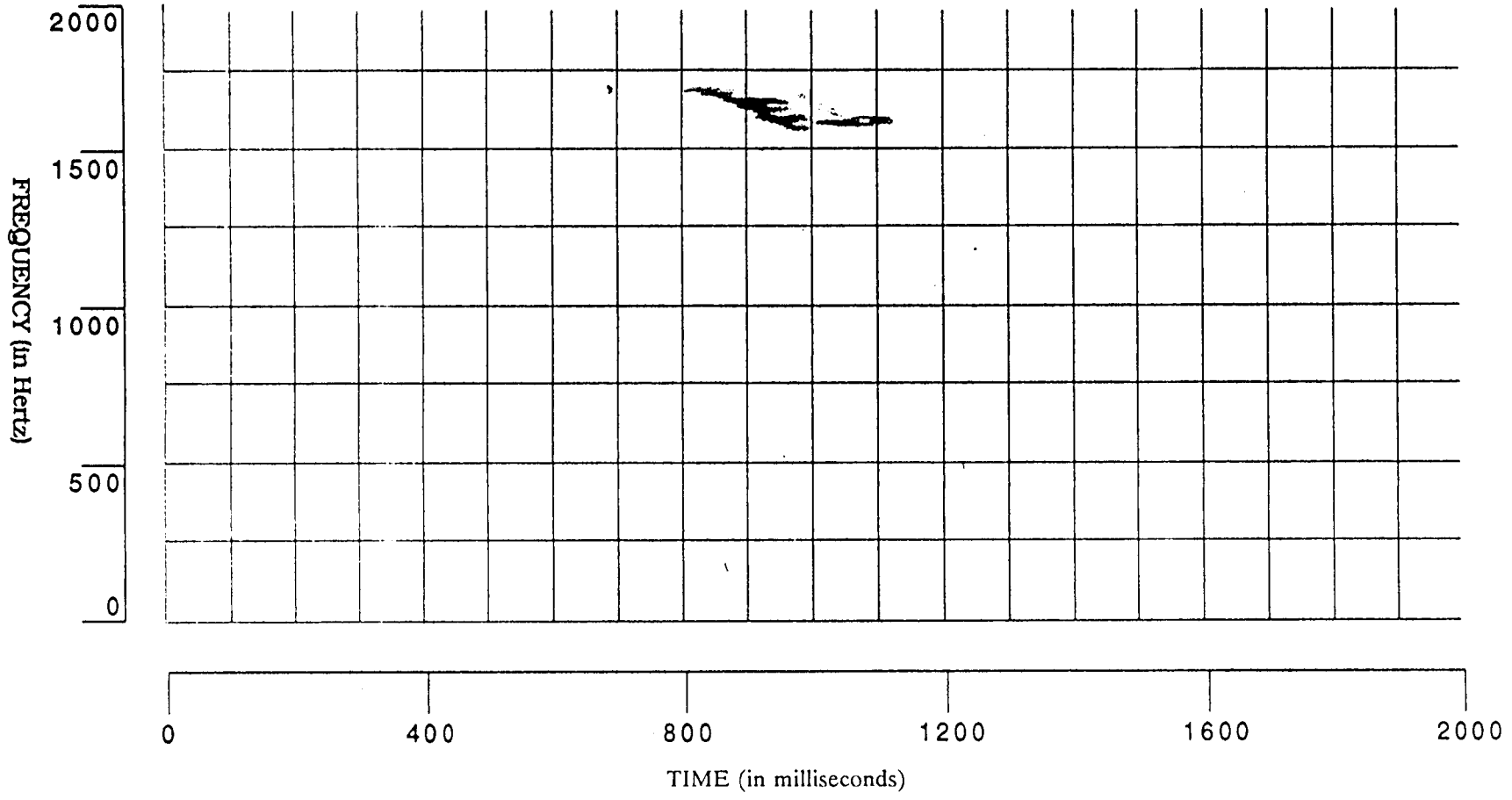

Figure 15 Spectrogram of Alarm call

Alarm calls were heard on three different occasions during the study at the San Diego Zoo and were given by a subadult male and an adult female. They were given in response to predators in close proximity. On two occasions, the alarm call was given in response to a passing domestic cat (*Felis* sp.) and on the third occasion for a bird (species unknown) sitting close to the enclosure.

During each occurrence, the alarm call drew the attention of all the individuals and was followed by flight reactions. Within a few seconds, all of them retreated to the upper part of the enclosure, such as high bamboo stumps, and climbed on the wall of the enclosure. After hearing the call, all the individuals became alert and modified their sitting posture to inspect the passing predator while being silent. During each occurrence, individuals were seen sitting close to each other and the mother and infant were in the center. Later they came in groups of two to three to inspect the possible predator at closed proximity.

In the case of the domestic cat, which was passing by the bedroom, one of the subadult males responded to its presence by emitting an alarm call and then climbing to a higher position. While sitting and staring at the predator, many individuals gave a series of alarm barks. After a few seconds, all the individuals inspected by peeping through the window of the bedrooms. Meanwhile, the cat disappeared from view. A few moments later, the tension among the langurs eased and activity resumed.

On another occasion, the alarm call was given in response to a bird that flew close to the enclosure and sat on a nearby tree. The call was emitted by an

adult female when all the individuals were feeding on the ground. Soon after hearing the call, everyone ran to the upper parts of the enclosure, away from the bird, leaving the ground empty. Several minutes later, feeding on the ground resumed.

Alarm calls were reported by the zookeepers on various occasions. According to one of the zookeepers at San Diego Zoo, an adult male responded with an alarm call to a coiled rope carried by one of the zookeepers to install in an enclosure as a climbing structure. The adult male emitted the call, presumably relating the coiled rope to a snake. Also, alarm calls were uttered when the zookeepers brought nets to catch sick animals for treatment and periodic inspections. The alarm calls uttered during these instances were reported to be distinctly different from one another.

According to one of the zookeepers at San Diego Zoo, the langurs responded with alarm calls to still photographs shown from a magazine. Individuals of all age groups, except infants and juveniles, gave alarm calls to the photographs of tiger (*Panthera* sp.), leopard (*Panthera* sp.), salamander (species unknown) and colorful frogs (*Rana* sp.). Juveniles uttered screams and squeals during these instances. When the same experiment was repeated by showing the still photographs of a house sparrow no reaction was observed.

Alarm Bark

Alarm bark was a short tonal unit with the presence of formants. The call duration was 0.1 seconds and the frequency range was between 0 and 2 kHz (Figure 16).

The alarm bark was uttered by all individuals except juveniles and infants. The alarm bark was given in response to the appearance of a predator at a distance. The call induced alertness among all the individuals of the group. During the utterance, the body was stiff and retracted and the tail was folded inwards. The mouth was half open and the teeth were covered by lips. On some occasions, alarm barks were uttered after alarm calls. I recorded the continuous repetition of up to seven alarm barks.

According to zookeepers at the San Diego Zoo, during late evening hours, adult females were seen charging domestic cats, who were walking adjacent to the bedroom, with continuous alarm barks. The zookeeper also said that alarm barks were uttered by adult females when photographs of different species of cats were shown from a magazine.

Threat cough

Threat cough was a non-tonal unit with slightly modulated harmonic frequency. The duration of the call was 1.0 second and the frequency range was between 0 and 8 kHz (Figure 17). The call occurred in regular or irregular multiples of two to four.

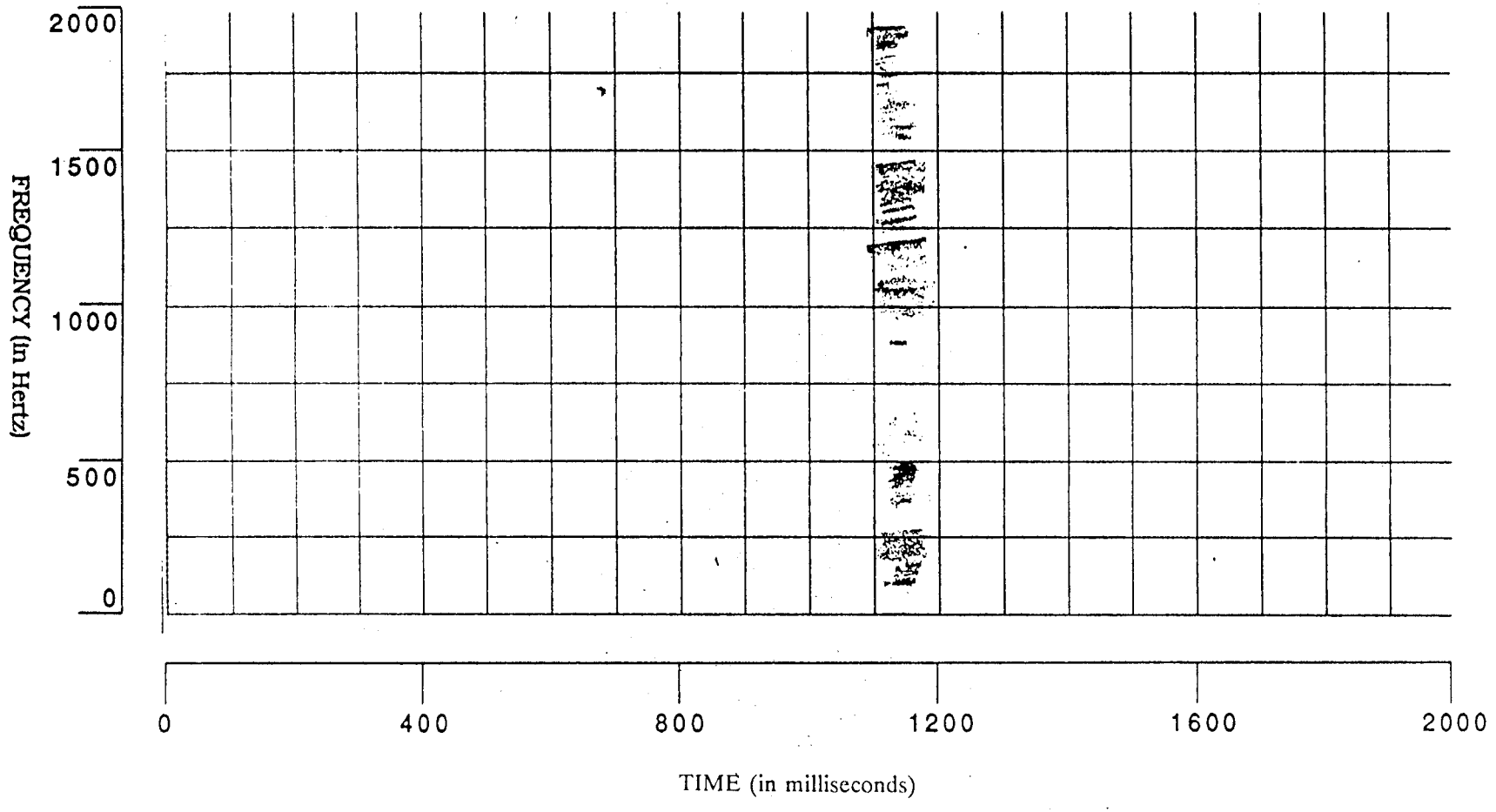

Figure 16 Spectrogram of Alarm Bark

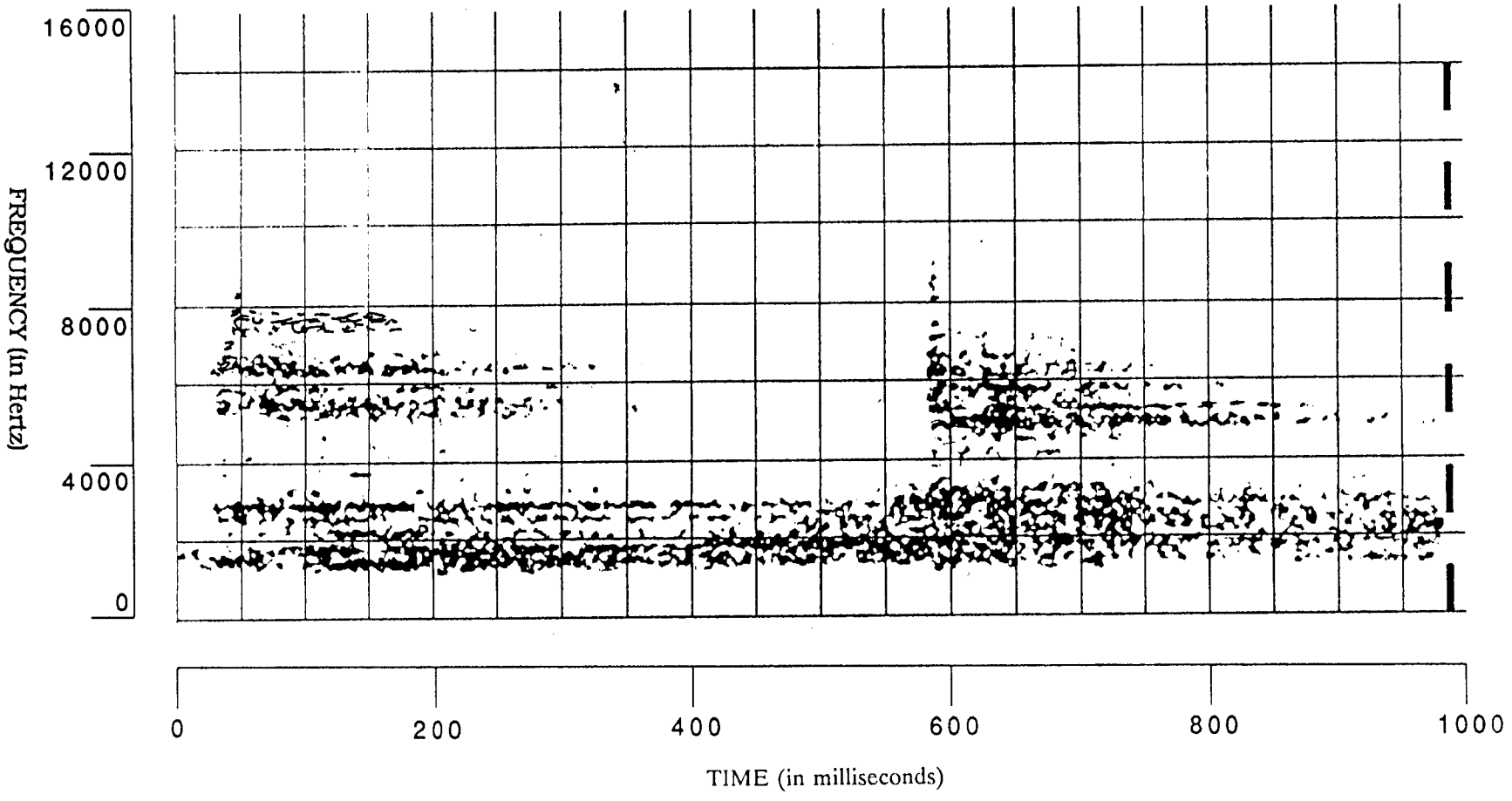

Figure 17 Spectrogram of Threat Cough

Threat coughs were uttered by individuals of all age groups except infants and juveniles. During the utterance, the emitter was standing bipedal with the eyebrows raised, the mouth half open and the teeth covered by lips. The call was given to the human observer on many occasions when the microphone was pointed towards the individual in close proximity. It brought all the individuals of the group to observe. Threat cough was also uttered during feeding hours and exchanged between individuals during agonistic interactions. During some instances, a threat cough was accompanied by a charge by the emitter and in other instances, it was followed by a series of greeting calls.

Up to four repetitions of threat coughs were recorded. The threat cough given by the adult male and females brought alertness among all individuals, and they responded by moving away from the emitter, ceasing all activities. Similar calls given by subadults did not yield the same response.

In Metro Washington Park Zoo, a threat cough exchange was observed between hanuman langurs (*P. entellus*) of the neighboring enclosure and *P. francoisi.* The behavior involved during the vocalization were teeth smear, stare and threat displays such as charging, jumping and occasional bipedal walking.

Low cough

Low cough vocalizations were short duration tonal units. The duration of the call varied from 0.1 to 0.3 seconds and the frequency range was between 1 and

4.5 kHz (Figure 18). The calls were uttered as singles or in multiples of two or three.

Low cough was recorded only during the post-transfer operations at the San Diego Zoo. A detailed description of the translocation operation is given at the end of the chapter. The calls were uttered by adult females, subadult males and females when they entered the enclosure where the adult female (mother) and the infant were held. The call was followed by bark vocalizations and attracted other individuals, presumably whoever heard the vocalization, to the scene. The individuals uttering the call were hesitant and tense while entering into the enclosure where the mother and infant were held. Conversational exchange of low coughs was observed among all the individuals except juveniles and infants.

The low cough was also given by the isolated mother a few minutes before the start of the translocation operation. The call was in response to approaching zookeepers. The call was accompanied by pacing, alertness and restless behaviors. During the utterance, the mouth was half open, the teeth were covered with lips, and the eyes were completely open.

Bark

Bark vocalizations were narrowly spaced harmonic tonal units uttered in single or continuous multiples of three to four. The duration of the vocalization was 0.45 seconds and the frequency range was between 1.5 to 6.5 kHz (Figure 19). The energy concentration is at the lower three-fourths of the harmonics.

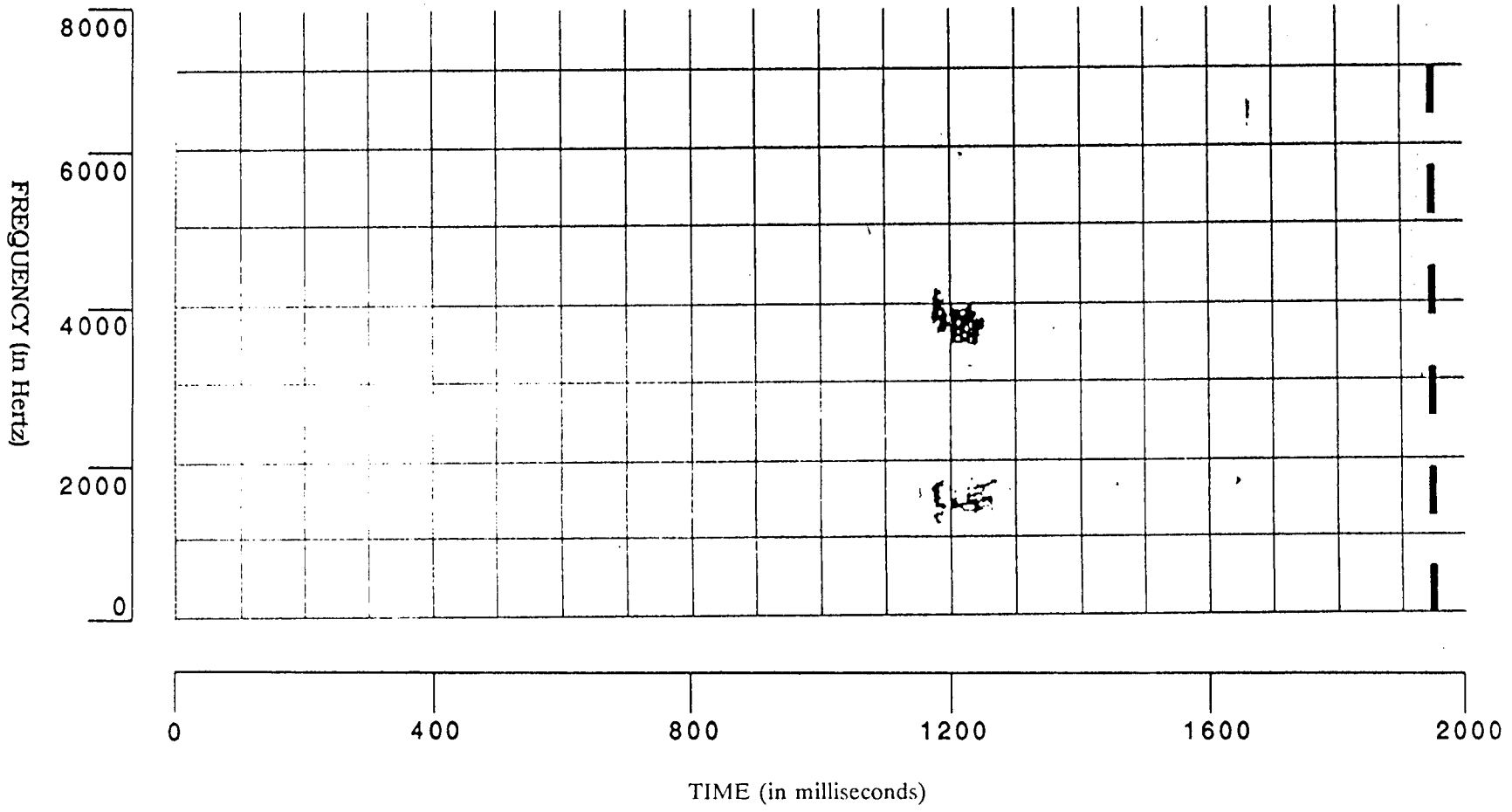

Figure 18 Spectrogram of Low cough

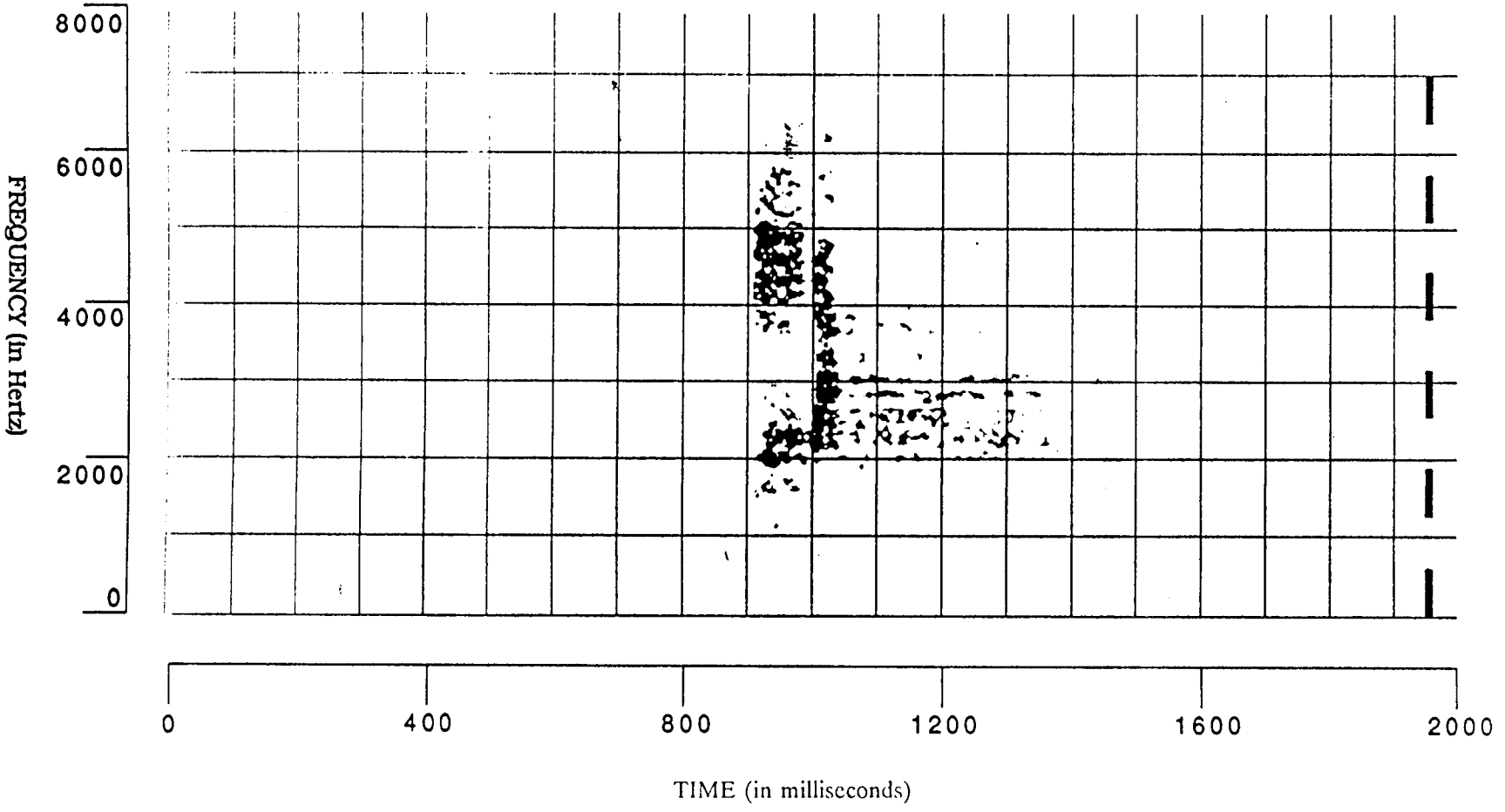

Figure 19 Spectrogram of Bark

Bark was uttered by individuals of all age groups except infants. The call was of short exhalation and was exchanged among individuals during play fighting and grooming. On many occasions, the bark was given as a threat gesture to passing zoo visitors. During such instances, the animals were seen standing bipedal and tossing their head while uttering the sound. Bark vocalizations were also uttered by subadult males and females during play chase. The play by subadults included walking backwards with their eyes closed. Barks were also uttered when an individual's tail was bitten by a playmate.

On several occasions, barks were uttered during the late morning hours towards incoming people, including the zookeepers, possibly expecting food. The vocalization under such circumstances were uttered by most of the members. Repetition of bark vocalizations were recorded up to six times.

Whoop

Whoop vocalizations were slightly modulated long duration tonal units. The energy concentration is distributed in the second harmonic. The harmonics were broadly spaced and stretched horizontally. The duration of the call was 1.2 seconds and the frequency distribution was between 0 and 1.3 kHz (Figure 20). The calls were uttered in single or in irregular multiples of two or three.

Whoop calls were given by all the individuals of the group except infants. During certain periods, the whoop calls were prolonged and loud. The calls involved a deep inhalation and exhalation with the facial muscle protruded and the

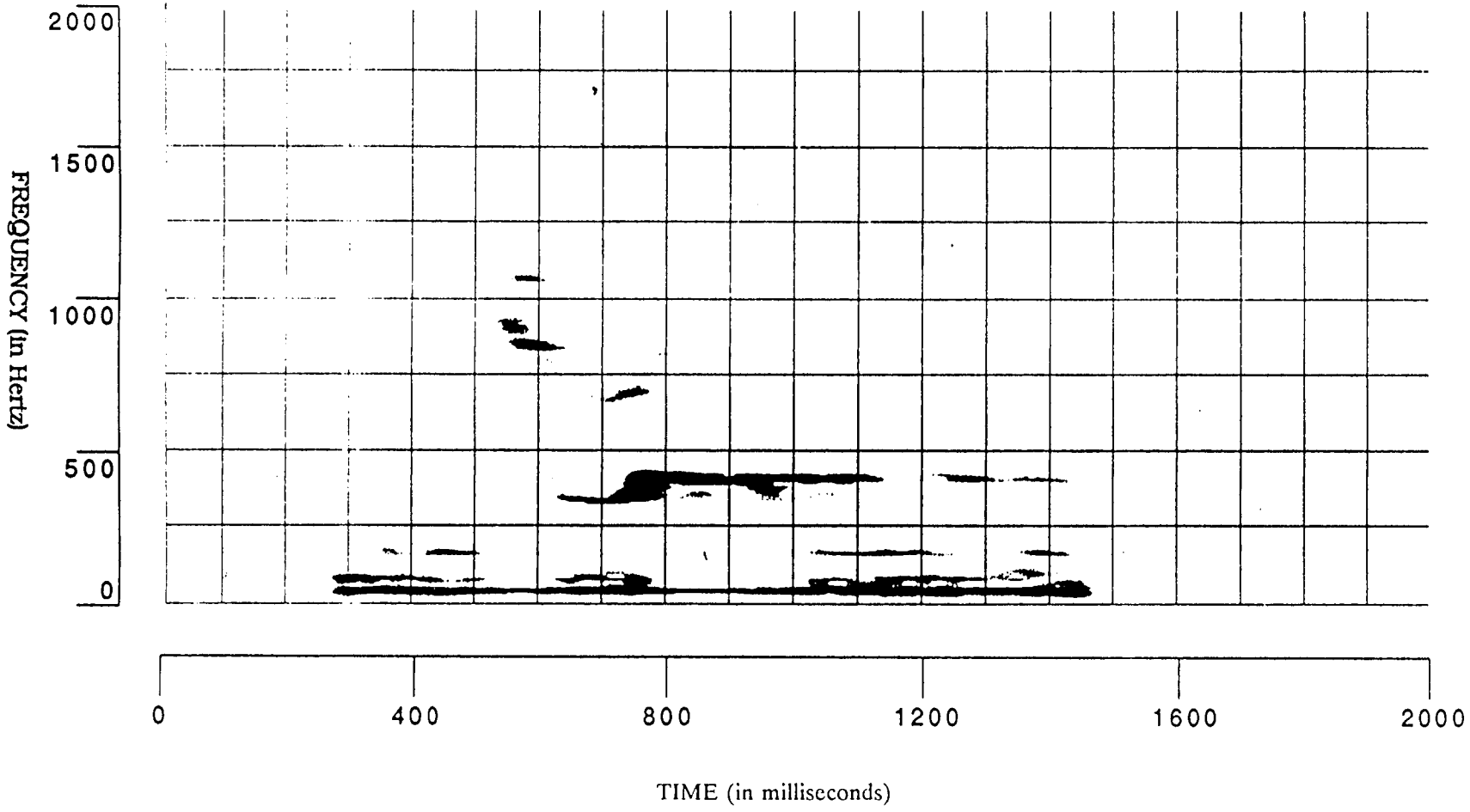

Figure 20 Spectrogram of Whoop

mouth half open. During the vocalization, the body appeared to slightly jerk forward. The calls were uttered while the emitter was sitting.

On two occasions, at San Diego Zoo, the adult male uttered the whoop call and left the bedroom. All the individuals in the bedroom followed the adult male to the outdoor enclosure. Whoop calls followed by squeals were also uttered by subadult males, after seeing the zookeeper preparing food to feed the animals.

At the Metro Washington Park Zoo, whoop calls uttered by common langurs (*P. entellus*) of the adjacent enclosure drew the attention of the *P. francoisi*. During certain occasions, whoop calls uttered by *P. entellus* stimulated *P. francoisi* to vocalize similarly.

At San Diego Zoo, whoop calls were uttered when the individuals were separated in the bedrooms for medical examination or when removed from the enclosure for treatment. The whoop calls were also uttered by the isolated mother who with her infant was later translocated to another Zoo (description of the translocation operation is given at the end of the chapter). After uttering the call, the adult female was seen pacing up and down the cage, attempting to view other individuals who were in the outdoor enclosure.

Contact greet

The call was a repeated monosyllable including nearly evenly spaced tonal units. The duration of the contact greet varied from 0.5 to 0.8 seconds and the

frequency range was between 0 and 14 kHz (Figure 21). Both participants gave a continuous repetition of the contact greet up to 12 times.

The vocalization was uttered by all individuals except infants. Contact greet involved interaction among two or more individuals, with at least one and some times both giving the call. The vocalization occurred just before establishing physical contact by hugging. Physical contact lasted only a few seconds. When in sitting posture, the individuals involved in the contact greet embraced each other with their forelimbs. The common orientation patterns were face-to-face and side-by-side. Contact greet vocalizations were also followed by lipsmacking, teeth grimace, mouth to mouth contact, stare, grooming and on some occasions mounting, if the recipient of the greet was the adult male.

Contact greet calls also were uttered by individuals intervening in an agonistic interaction such as a chase, post fight situations or during excitement, huddling, or when the emitter was drawing attention for physical contact. The physical contact acted as a reassurance, and the agonistic interactions were stopped after the contact greet vocalization. The vocalization was also uttered during play and wrestling.

According to one of the zookeepers at San Diego Zoo, contact greets have been observed when the animals were reunited after a few days of separation for medical examination. On certain occasions, adult females attempted to grab the zookeepers hand and embrace them while giving the vocalization.

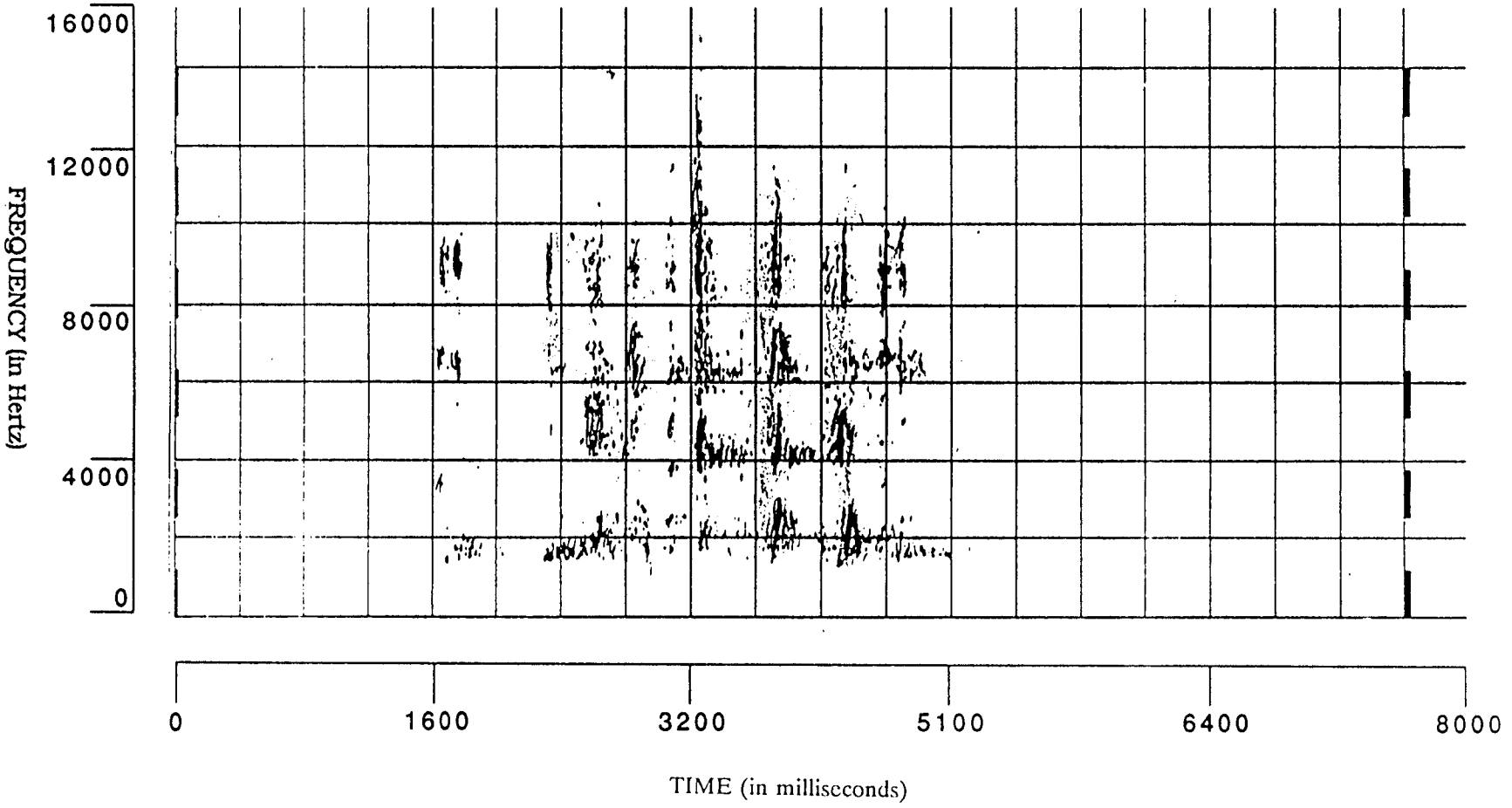

Figure 21 Spectrogram of Contact greet

Threat Scream

Threat scream was a long and loud sound with irregularly modulated tonal units. The calls were multisyllable harmonic units. The harmonics of the second syllable ended with a higher frequency. The duration of the call was 2.8 seconds and the frequency range was between 0.5 to 13.5 kHz (Figure 22). The energy concentration was in the frequency range of 3.5 to 4.0 kHz.

The calls were uttered by all individuals except the adult male and infants. They were uttered in response to an attack or threat. During the utterance, the mouth was half opened and the face retracted with eyes half closed. On many occasions, threat scream was followed by urination. Threat screams were also followed by alarm calls. During such instances, the individual's mouth was completely open followed by contact greet.

Threat scream was also uttered by a subadult male while snatching the infant from its mother or when the mother refused to give up its infant. The continuous utterance of the calls was recorded up to 4 times. Threat scream was also uttered by juveniles when photographs of elephants (*Elephas maximus*) from a magazine were shown, and while I was pointing the microphone in close proximity.

Grunt

Grunt vocalization was a short tonal unit with the energy concentration in the first harmonic. The frequency range of the broadly spaced parabolic harmonics

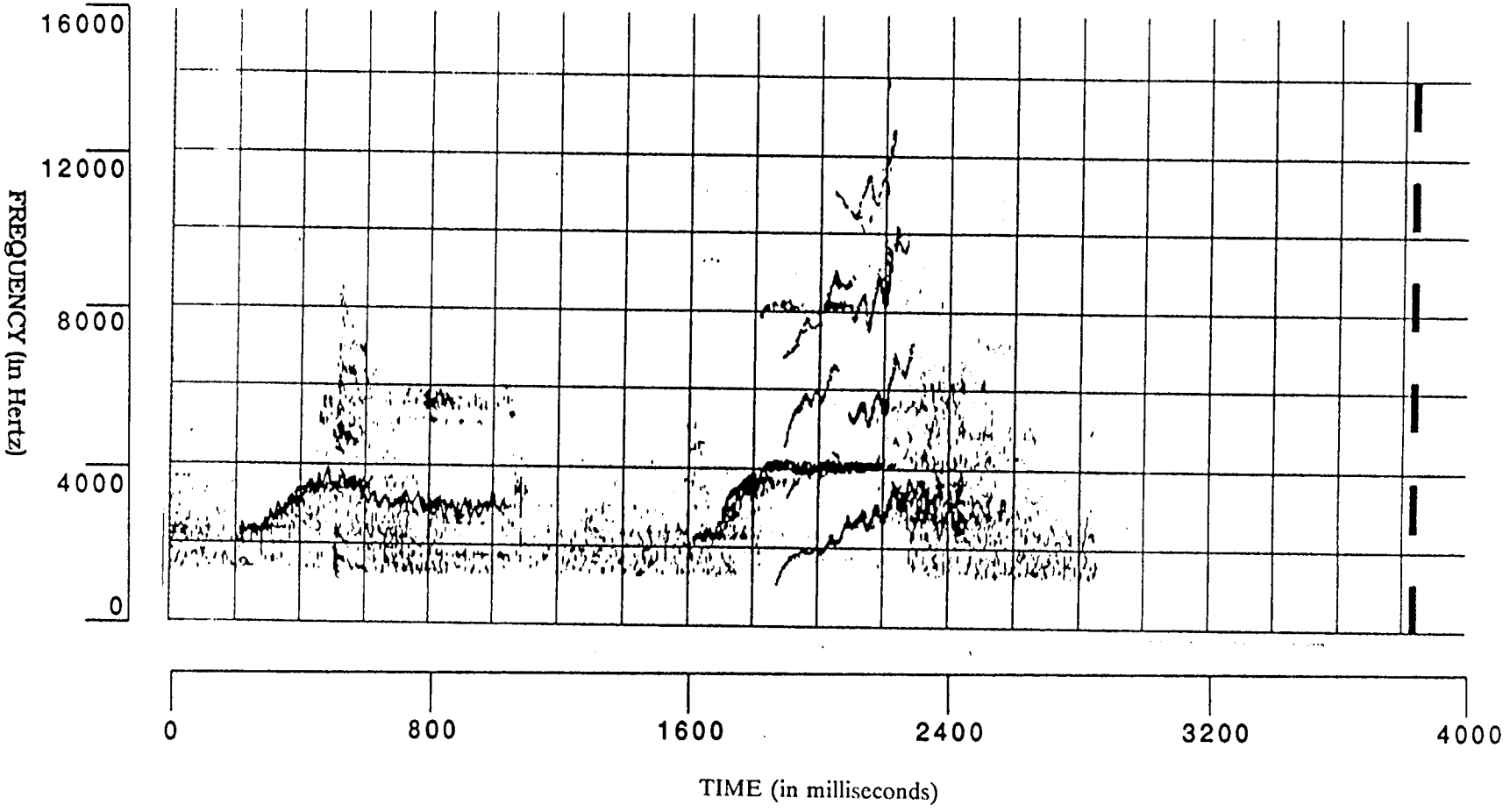

Figure 22 Spectrogram of Threat scream

was between 0 and 8 kHz. The duration of the vocalization was 0.15 seconds (Figure 23).

The call was given by individuals of all age groups except juveniles and infants during agonistic interactions among the group members. It was once recorded during a play fight by a subadult female. During another instance, a grunt was uttered by the adult female with the infant when the subadult was trying to pull the tail of the infant. The facial expression observed during the grunt included a partially closed mouth and opened eyes. The calls were uttered in postures such as sitting and, standing and while walking.

Squeak

Squeaks were short duration frequency modulated vocalizations. The call was a low sound with a duration of 0.4 seconds and a frequency range between 2 and 9 kHz (Figure 24). The energy concentration is in the first harmonic.

Squeak vocalizations were uttered only by subadult males and juveniles during fighting and agonistic interactions. The vocalizations were presumed to be defensive; on certain occasions the emitter was seen running away from the scene soon after utterance. Squeaks were also uttered while snatching the infant from the adult female and during allomothering behavior. The vocalization involved submissive expressions such as a retracted shoulder and tail.

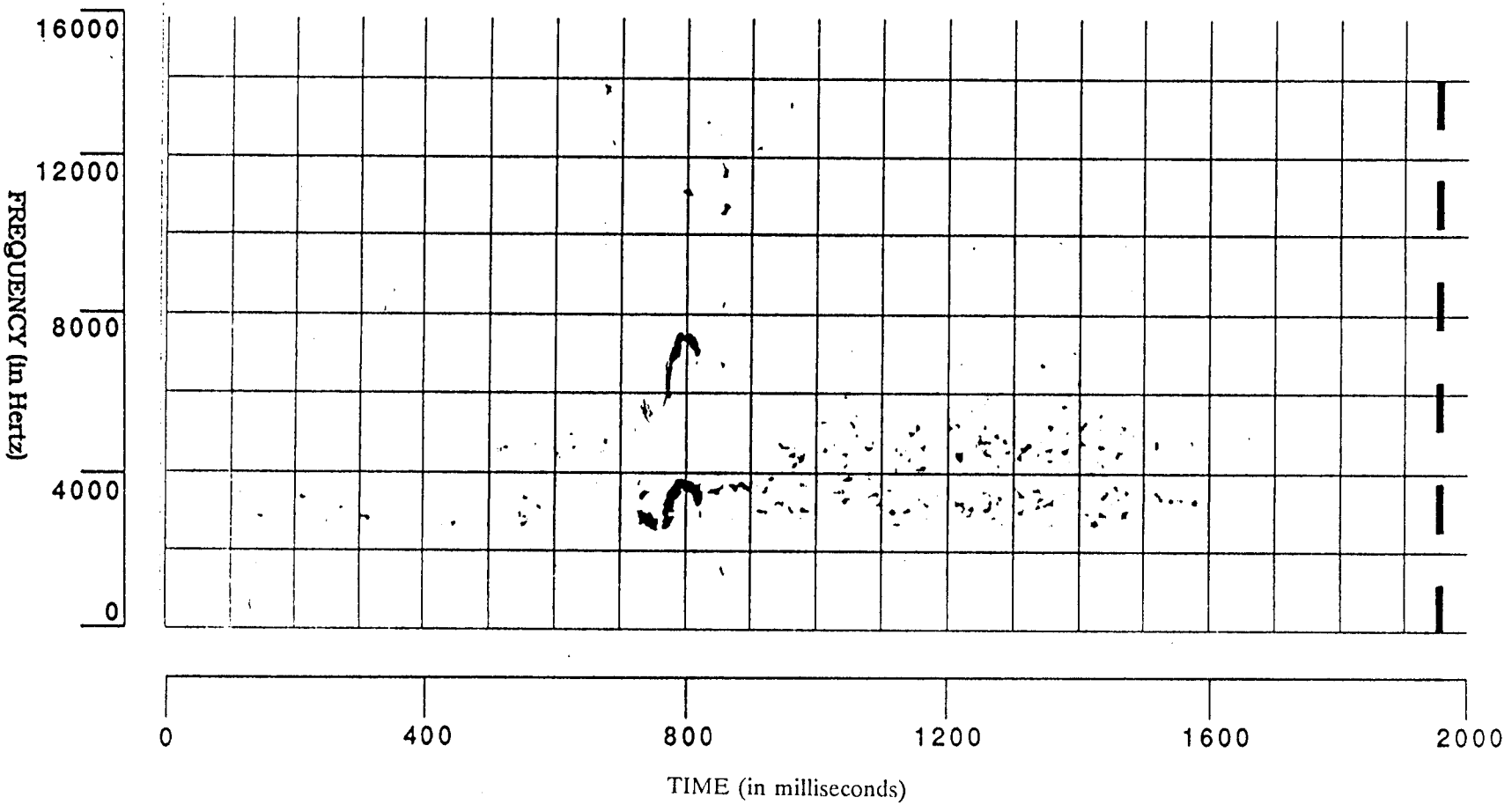

Figure 23 Spectrogram of Grunt

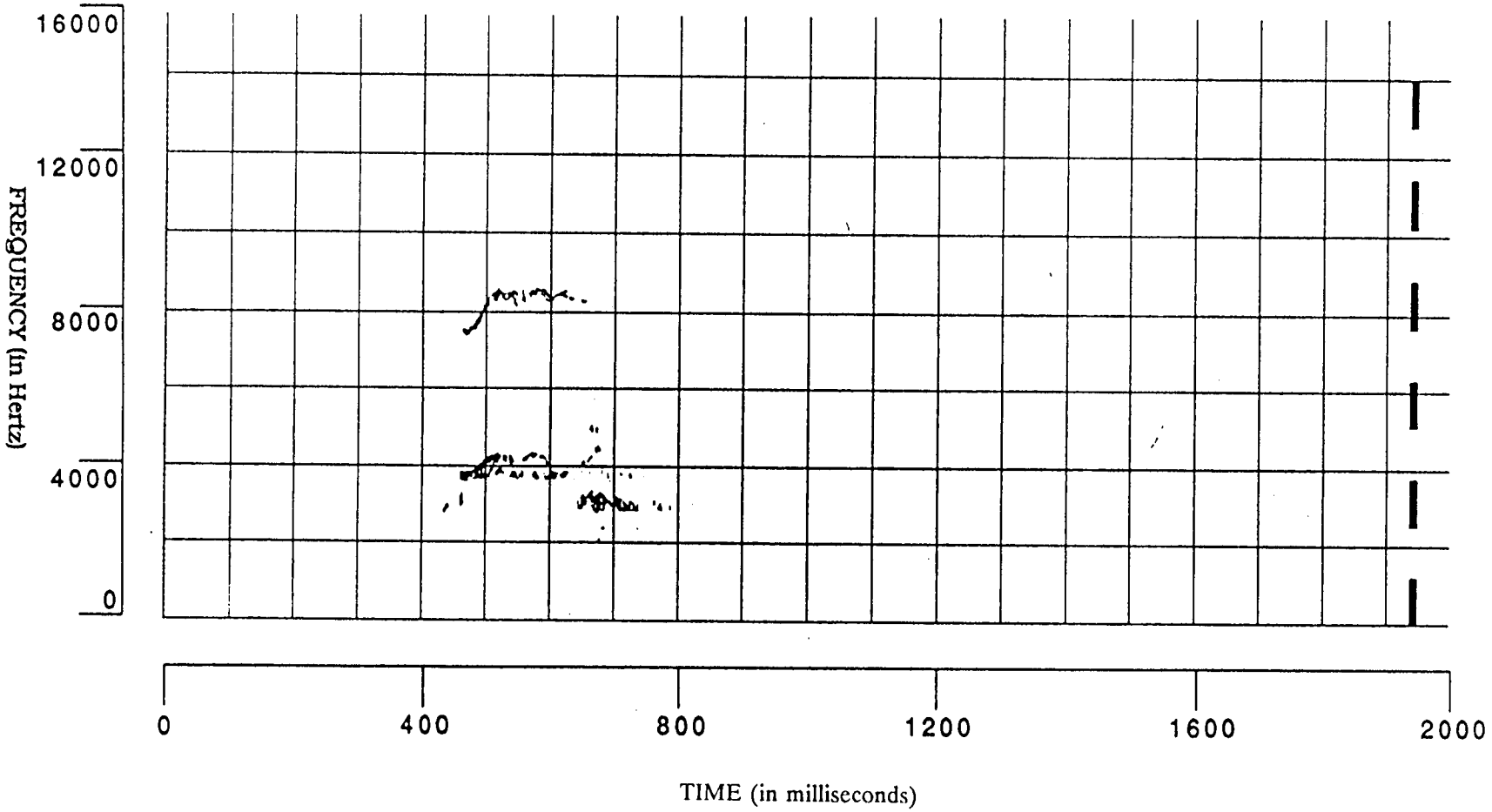

Figure 24 Spectrogram of Squeak

Squeal

Squeals were several discrete and evenly spaced harmonic, frequency modulated, loud tonal units. They were long multisyllable calls with irregularly modulated frequency. The harmonics were broadly spaced in the first syllable. Squeal was repeated up to three times. The duration of call was up to 4 seconds and the frequency range was between 0 and 16 kHz (Figure 25).

Squeals were uttered by subadult males, females and juveniles. During play, subadult males and females responded with squeals when the emitter was involved in play fights. The facial expression included retracted facial muscles and shoulder with an occasional inward withdrawal of the tail. Squeals were also uttered during fights that occurred during feeding. The squeals uttered during such situations were the responses to snatching of food by the adult male or females. Squeals were also heard when the zookeeper was chopping food in front of the langurs during feeding hours.

Play scream

Play scream vocalizations were discrete harmonic, evenly spaced calls. They appeared to be slightly frequency modulated tonal units. The frequency range was between 0.8 kHz and 12.0 kHz (Figure 26). The harmonics were sometimes superimposed. Play screams were uttered singly or in irregular multiples of two or three. The call began with a non-tonal component and ended with a tonal component.

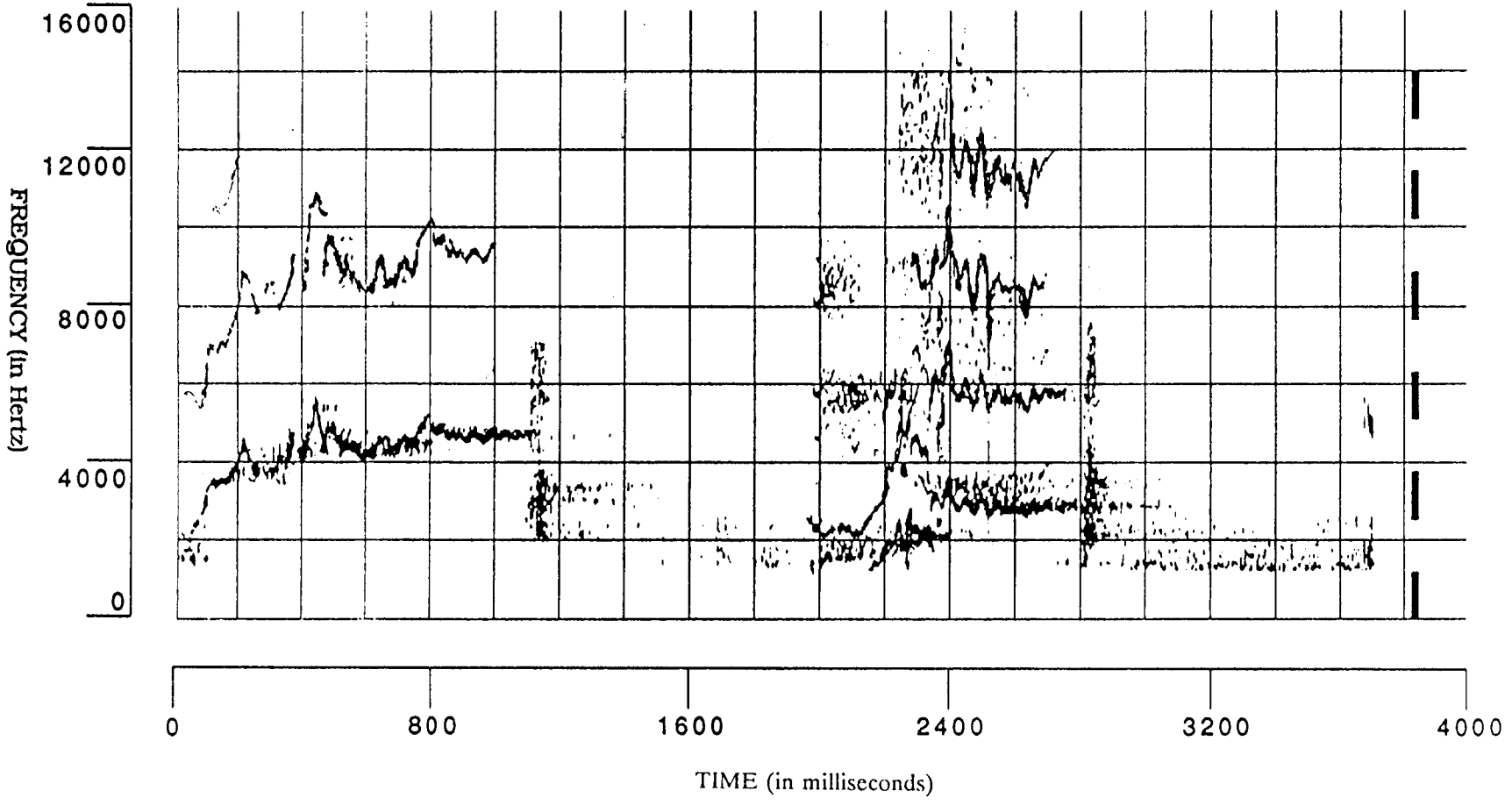

Figure 25 Spectrogram of Squeal

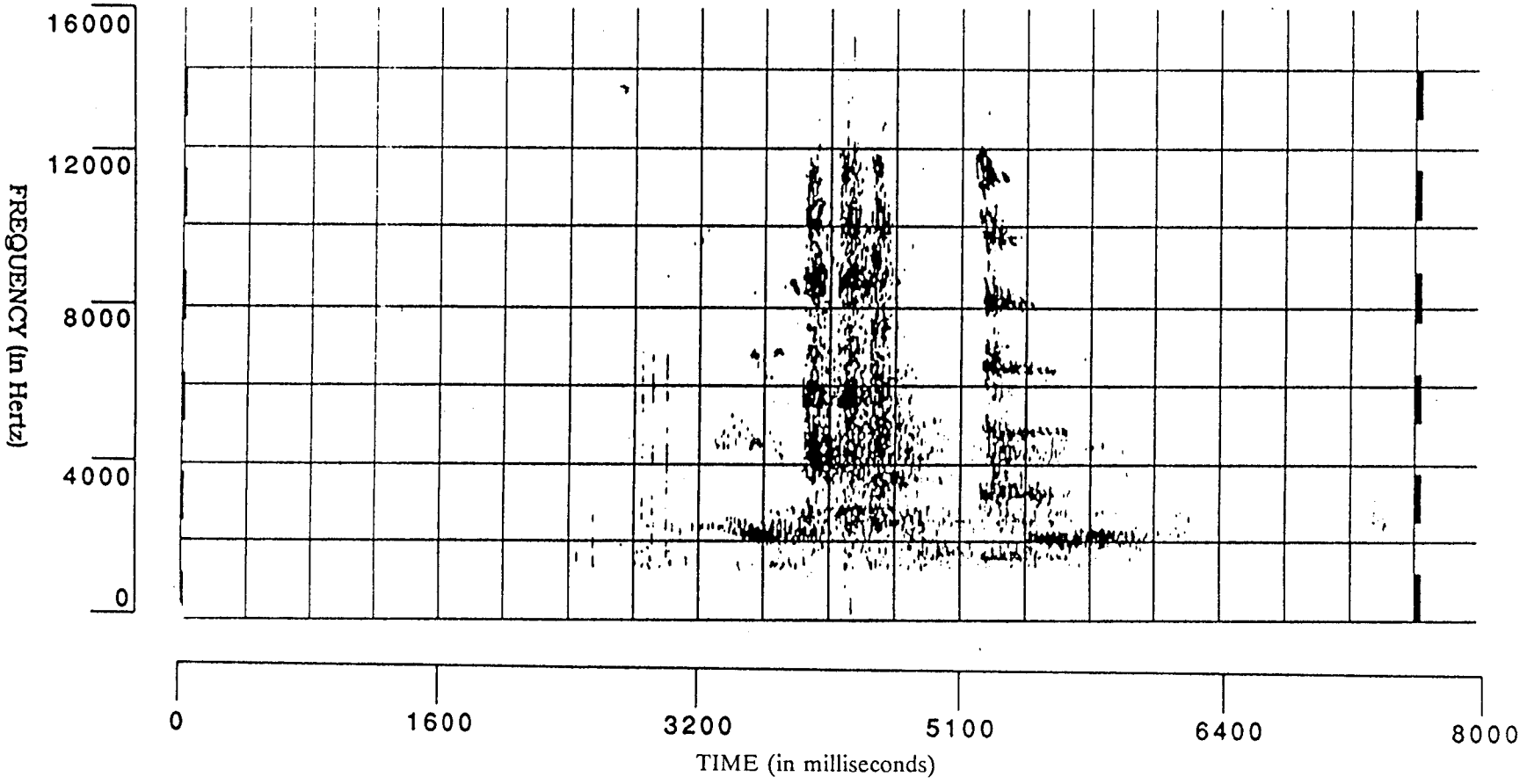

Figure 26 Spectrogram of Play scream

Play scream was uttered by all individuals except infants. On many occasions, play scream initiated play. The vocalization uttered during the chase was followed by play fighting, such as tail pulling, wrestling and somersaulting. During play scream, subadult males and females were seen kicking the opponent with their hind limbs. Play scream involved walking backwards with the eyes closed. Repetition of play scream was recorded up to 3 times. The facial expression of the vocalizer included retracted face, open mouth and partially closed eyes.

Exchange of play screams by subadult males with the neighboring Douc langurs (*P. nemaeus*) were observed at San Diego Zoo.

Screech

Screech was a loud tonal unit usually uttered in multiples of three. They were broadly spaced parabolic, harmonic, frequency modulated peaks. They occur in several discrete harmonic bands whose frequency ranges from 0.5 kHz to 13 kHz. The duration of the call was 0.35 seconds (Figure 27).

Screech vocalization has been recorded only during aggressive fights between the adult males and adult females. The calls were of long duration uttered only by adult females. The facial expressions include retracted cheek, exposed teeth and the completely opened eyes. The screech vocalization stops the activity of the group for a few seconds. Screech vocalizations were also observed when

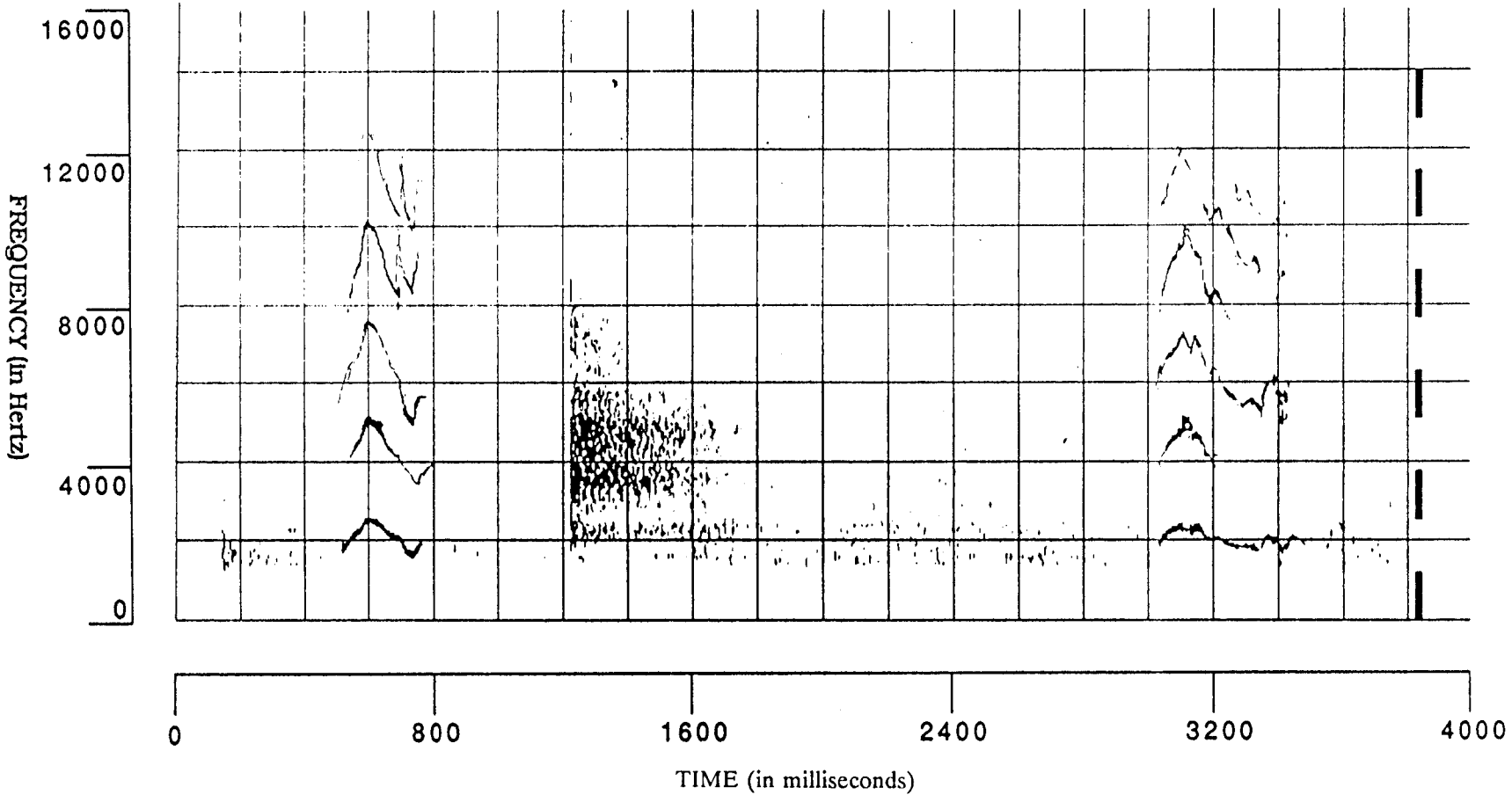

Figure 27 Spectrogram of screech

an adult female was forced to copulate with the adult male. Soon after the screech, the emitter was seen running away from the adult male.

Aaoo

Aaoo calls are low frequency non-tonal units uttered singly by subadult females during prefeeding hours. There were also uttered in multiples of two on some occasions. The duration of the call was 0.7 second and the frequency range was from 1.25 to 2.5 kHz (Figure 28). The exact context was not determined. The call, on certain occasions, initiated the adult male to utter whoop calls.

Infant Vocalizations

The following infant vocalizations were recorded at San Diego Zoo. Among the vocalizations recorded, the whistle was uttered most frequently. This presumably was due to rough handling of the infant by other members during allomothering, and occurred during the first five days of the infant's birth.

Cry

Cry vocalizations were long multisyllable frequency modulated tonal units with and broadly spaced harmonics. The harmonics were irregularly modulated. The energy concentration was at the second harmonic of the first syllable. The duration of the cry was 4.7 seconds and the frequency range was between 0.75 and 6 kHz (Figure 29). Cry vocalizations occurred in single or regular/irregular

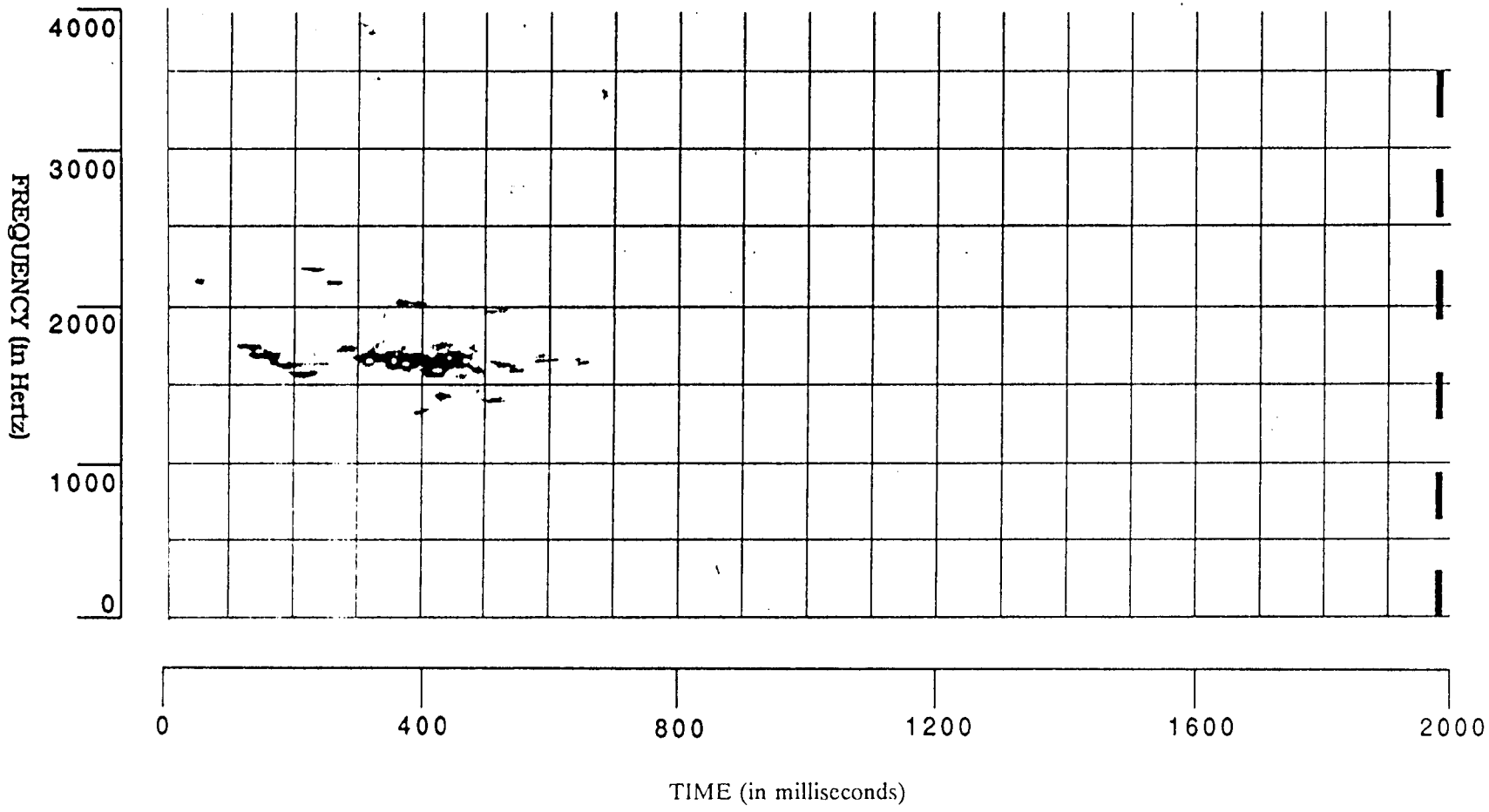

Figure 28 Spectrogram of Aaoo

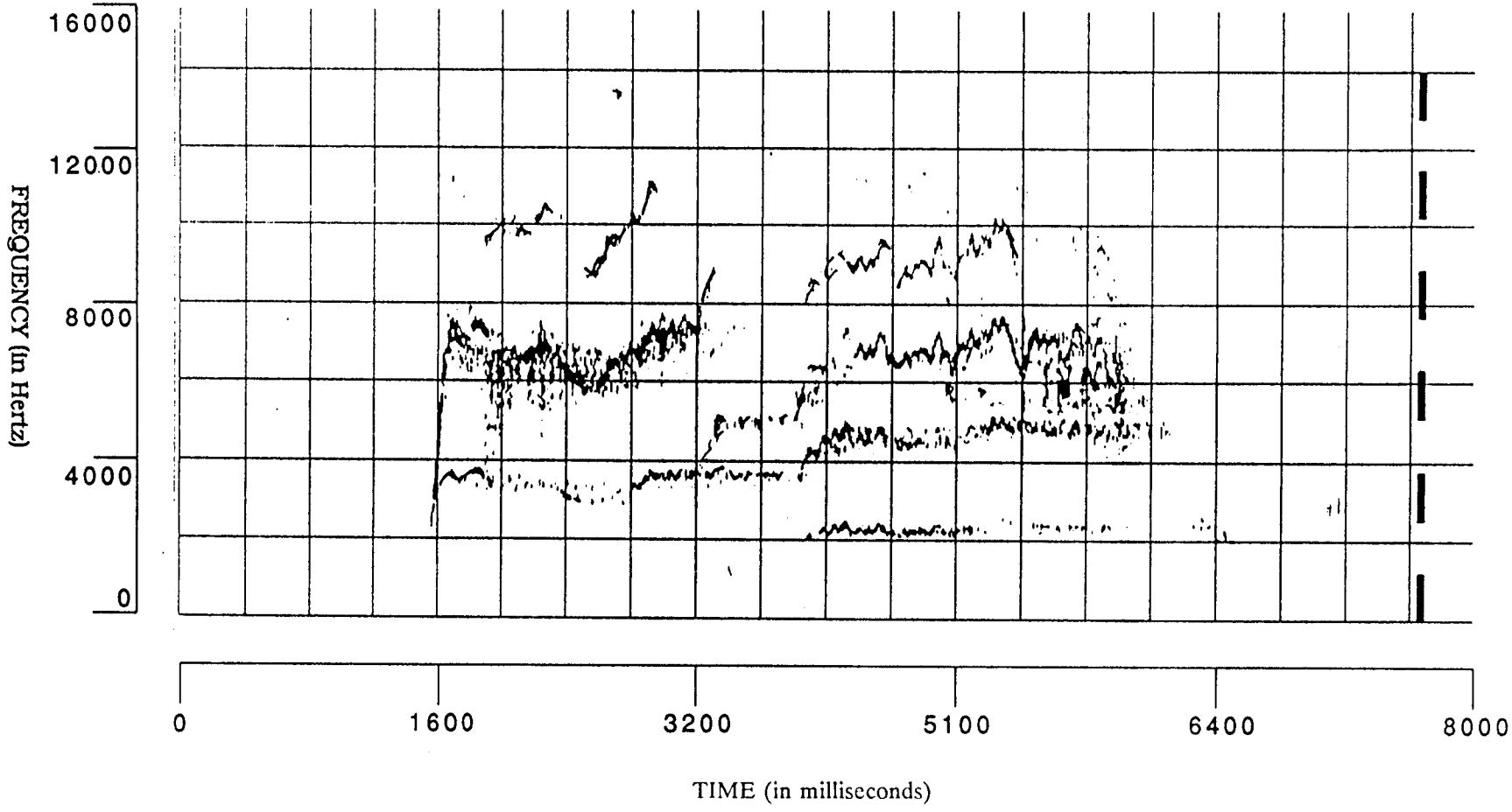

Figure 29 Spectrogram of Cry

multiples. During certain instances, such as rough handling of infants by other aunts, the cry was repeated up to 8 times.

Cry was also heard when the infant was snatched from the mother or from other members of the group. The mother responded to the cry by positioning herself toward the infant to get a view, if the infant was in someone's hand. Depending on the number of repetitions of the cry vocalization, the mother followed the individual carrying the infant very closely. The facial expression involved during the cry was closed eyes, opened mouth and retracted cheek muscle. The infant was seen clinging tightly to the body of the mother or aunt.

Qua

Qua vocalizations were narrowly spaced harmonics with frequency modulated tonal components. The duration of the call was 1.5 seconds and the frequency range was between 0.2 and 10 kHz (Figure 30). They occurred in multiples of two. On certain occasions, the vocalization was repeated continuously up to 5 times.

This vocalization was recorded during allomothering and rough handling. The individuals were seen kissing, grooming, head pushing and pulling the tail of the infant, while the infant was with the mother. On most occasions, the mother responded to the call by moving away from other individuals, sometimes giving threat barks. The infant was seen firmly holding the body of the mother with the face towards the abdomen of the mother.

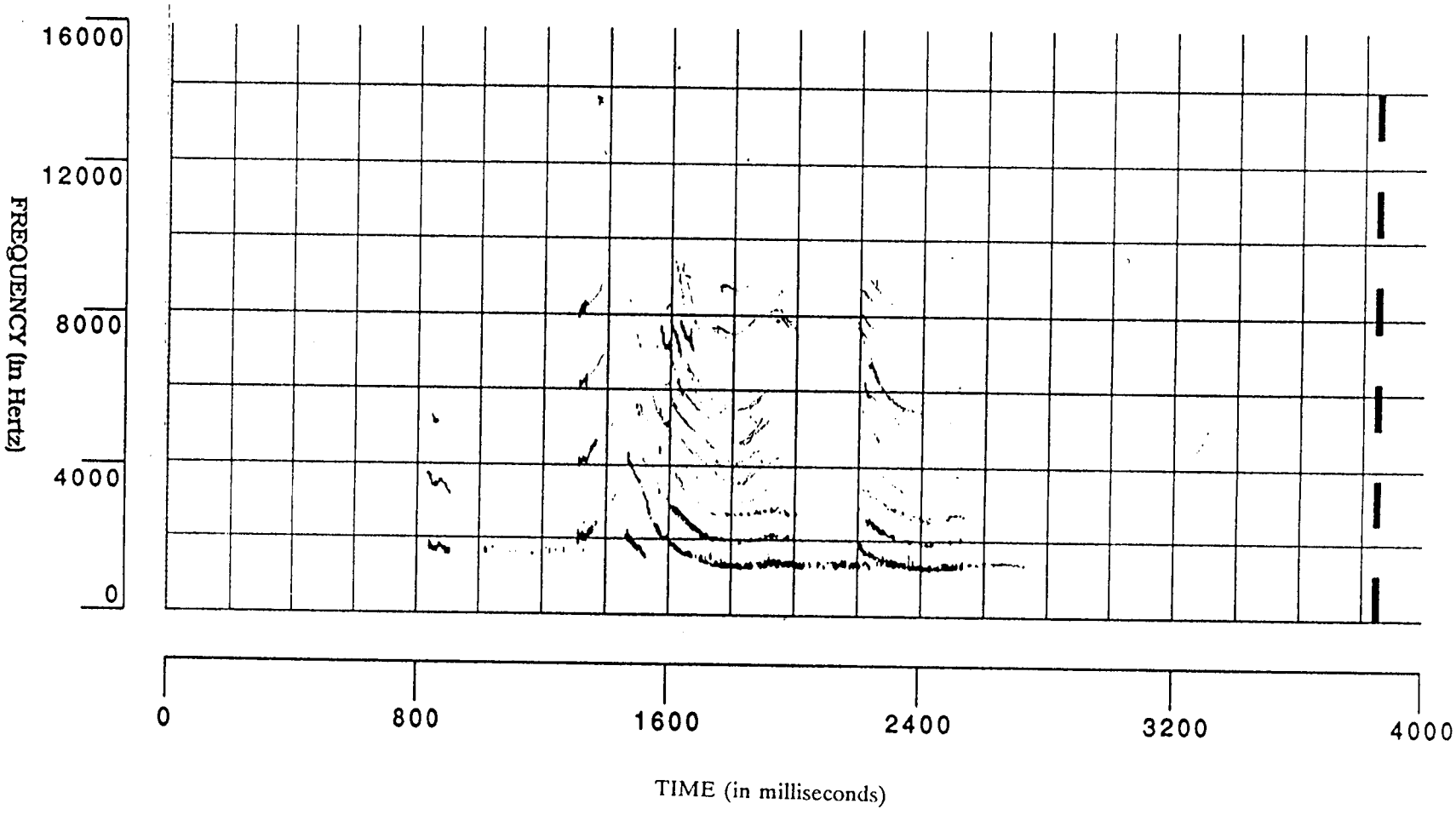

Figure 30 Spectrogram of Qua

Whistle

Whistle vocalizations were the longest of all the calls recorded during the study. The duration of the vocalization was up to 16 seconds. These were broadly spaced parabolic harmonics ending with a higher frequency. They were multisyllable vocalizations with the frequency range between 0.5 and 13 kHz (Figure 31).

The vocalization occurred when other individuals of the group attempted to snatch the infant from the mother by pulling the head, tail or leg of the infant. It is assumed that the infant suffers pain during the vocalization. On many occasions the mother responded to the call by retrieving the infant from other individuals. The mother responded to Whistle vocalizations by giving threat calls and sometimes was involved in severe fights to separate the infant from other individuals. During such situations, the mother and the infant changed their sitting posture to get away from the disturbing aunts. Repetition of the whistle vocalization was recorded up to 3 times.

Weaning scream

Weaning screams were loud and long with multisyllable, irregularly modulated harmonic tonal units. The harmonics of the first and the last syllable were evenly spaced. The energy concentration was in the first two harmonics. The duration of the vocalization was 0.2 seconds and the frequency range of the call was between 0.5 and 15.5 kHz (Figure 32).

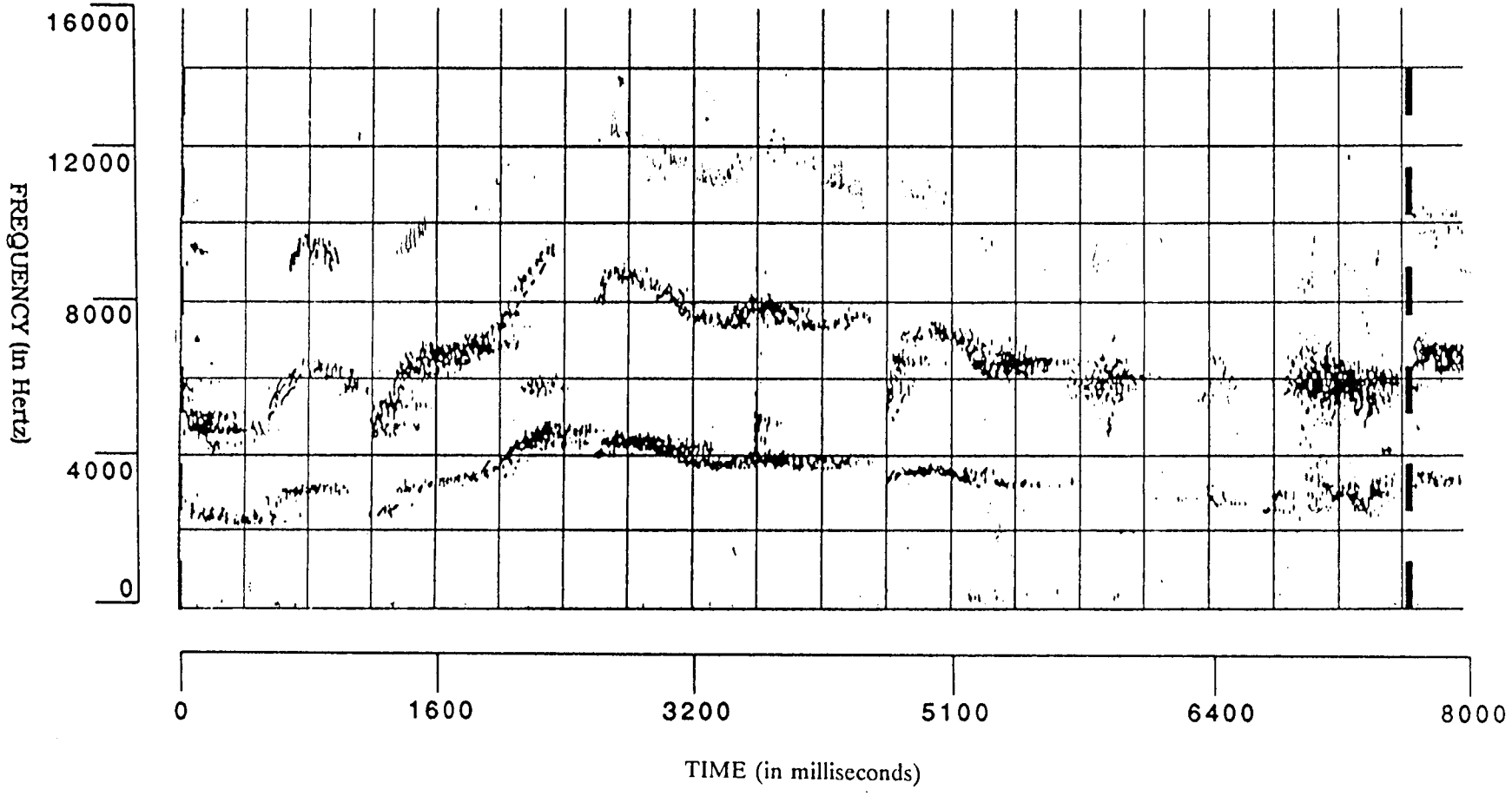

Figure 31 Spectrogram of Whistle

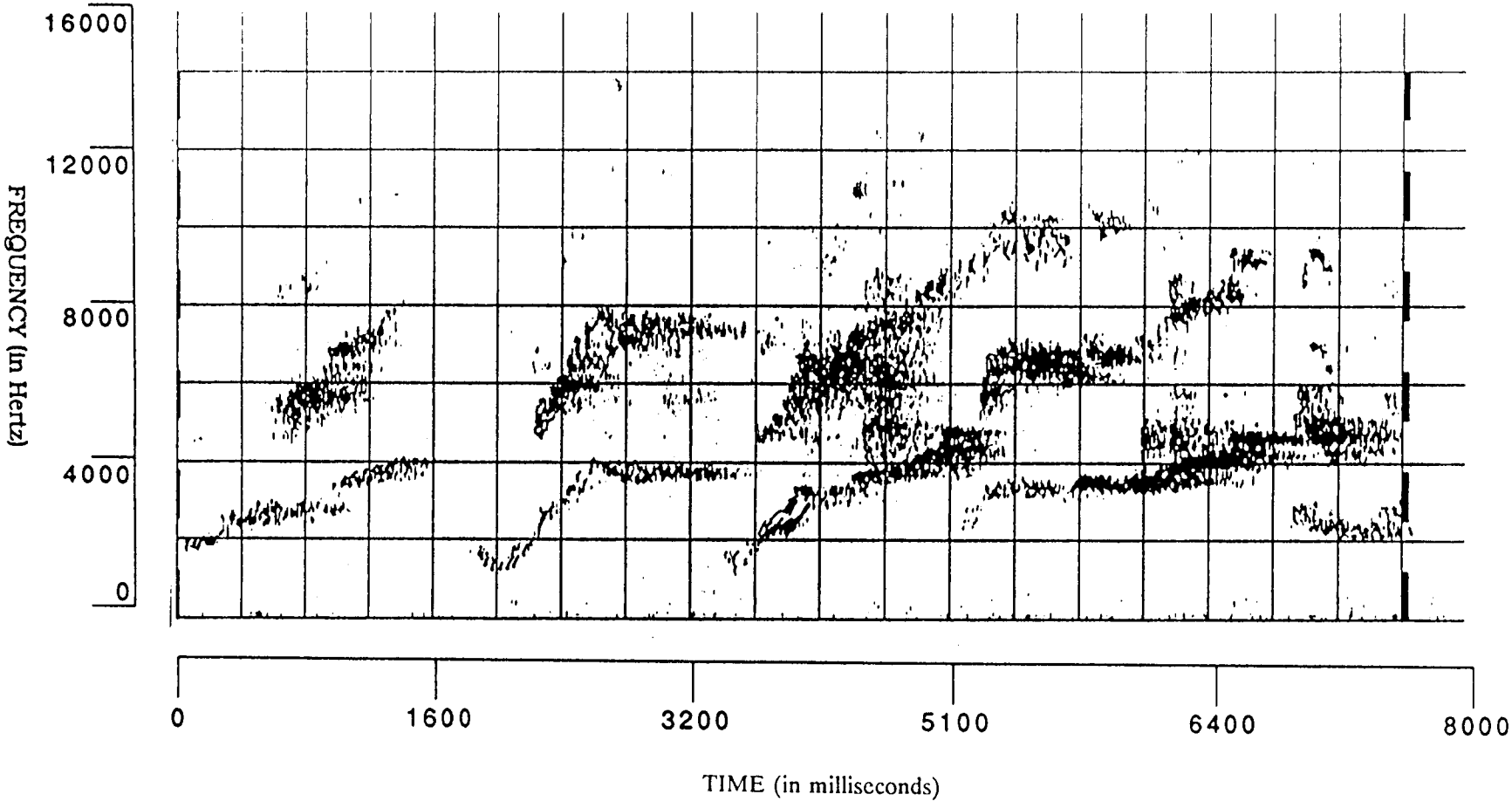

Figure 31 Spectrogram of Whistle contd.,

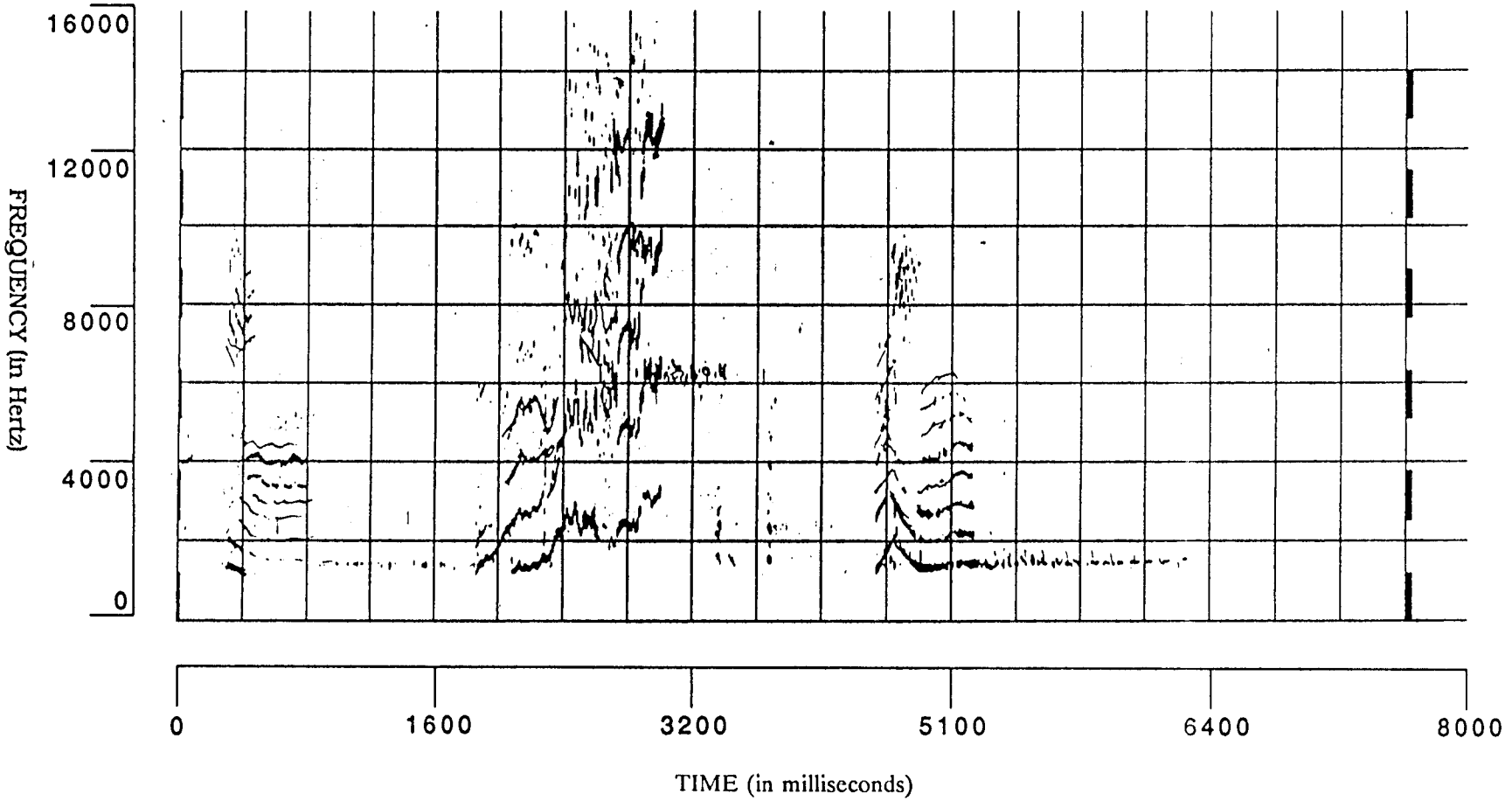

Figure 32 Spectrogram of Weaning scream

Weaning screams occurred when the infant was snatched while suckling. On most occasions, the infant was retrieved by the mother and the suckling resumed. The vocalization was also uttered when the mother refused to allow the infant to cling.

Weaning squeal

The weaning squeal vocalizations were irregularly modulated harmonic tonal units with a rise in frequency towards the end. The energy was concentrated at the end of the second harmonic. The call duration was 1.1 seconds and the frequency range was between 0.2 kHz to 12 kHz (Figure 33).

Weaning squeal was uttered when the mother changed the nursing position or refused to feed milk. Squeals were also uttered when the mother was grooming the infant. During such instances, the mother was seen lifting the infant by the tail and inspecting the anal region. The call was also given in response to rejection or loss of physical contact with the mother.

Responses by Mother to Playback of Infant Vocalizations

Playback of cry vocalizations was conducted at San Diego Zoo to investigate the response of the mother and other individuals of the group. The vocalization was replayed immediately after recording and the sound was aimed towards the mother and infant. During the replay, the mother lifted the face of the infant to verify the vocalization. As the vocalization was not uttered by the infant,

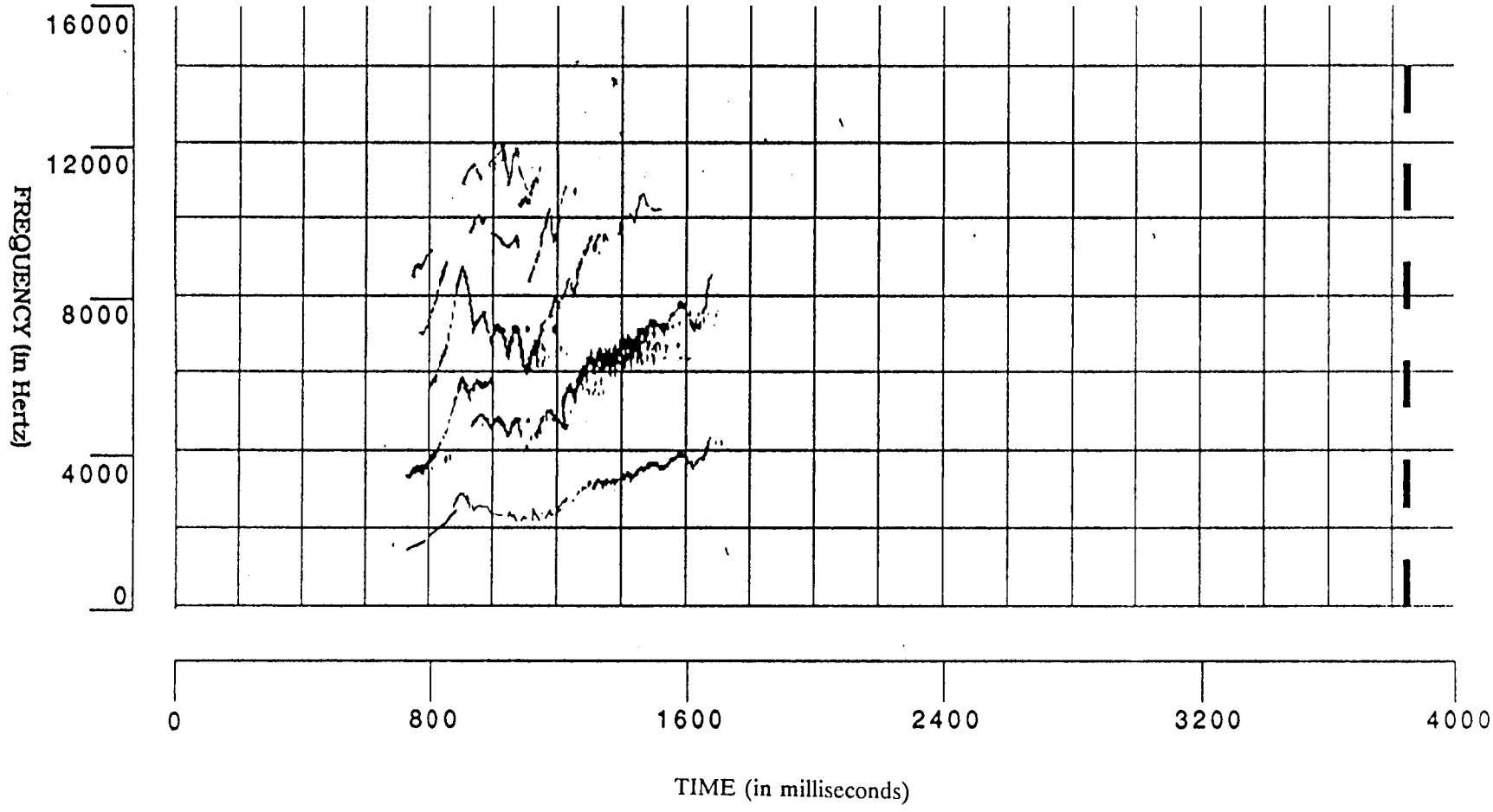

Figure 33 Spectrogram of Weaning squeal

the mother turned her head around to inspect the call. Other individuals in the group, especially the subadult males, uttered a series of squeals, presumably a threat to the replayed vocalization. Other adult females in the group also came and looked in the vicinity while surrounding the mother and the infant. The activities of the group resumed a few minutes after the replay was over.

Calls Documented By Other Human Observers

Loud Call

The following description of the loud call was obtained from the zookeepers at San Diego Zoo, as it did not occur during the study. For this reason, physical parameters of the calls were not obtained. According to zookeepers, the call was uttered only by the adult male during stressful conditions and was repeated more than 10 times during each utterance.

The call was uttered in response to noise generated by the disposal trucks that came regularly during the early morning hours. The garbage dump was located very close to the enclosure. The noise that occurred during the retrieval of garbage from the dump presumably agitated the adult male, which gave a series of loud calls. During vocalization, the adult male circled around the enclosure with threat displays, while other individuals in the group stopped activities to observe the situation. On some occasions, the individuals of the group focused their eyes toward the direction of sight where adult male was looking. The animals were also

seen standing bipedally inspecting the situation. The loud calls were sometimes accompanied with squeals by subadult males, females and juveniles.

According to the zookeeper at San Diego Zoo, similar vocalizations were also uttered by a captive guenon (*Cercopithecus* sp.) under similar conditions.

Type II Vocalizations

Type II vocalizations include three different patterns PSV 1, PSV 2 and PSV 3. PSV 1 and PSV 2 were recorded only at the Metro Washington Park Zoo, while PSV 3 was recorded at both zoos. However PSV 3 occurred only two times during the period of study at the San Diego Zoo and no stereotypic behavior was encountered.

All three types of calls recorded at the Metro Washington Park Zoo were accompanied by stereotypic pacing behavior. A diagrammatic representation of the stereotypic behavior is presented in Figure 34. On all the days of observation, vocalizations at the Metro Washington Park Zoo were uttered only between 12:05 PM and 1:35 PM or until the langurs were fed. Utterance of the calls was stopped soon after they were given food.

PSV 1

The vocalization was made up of evenly distributed and narrowly spaced harmonic tonal units. The frequency was slightly modulated with the energy distributed in the upper and lower harmonics. The duration of the vocalization was

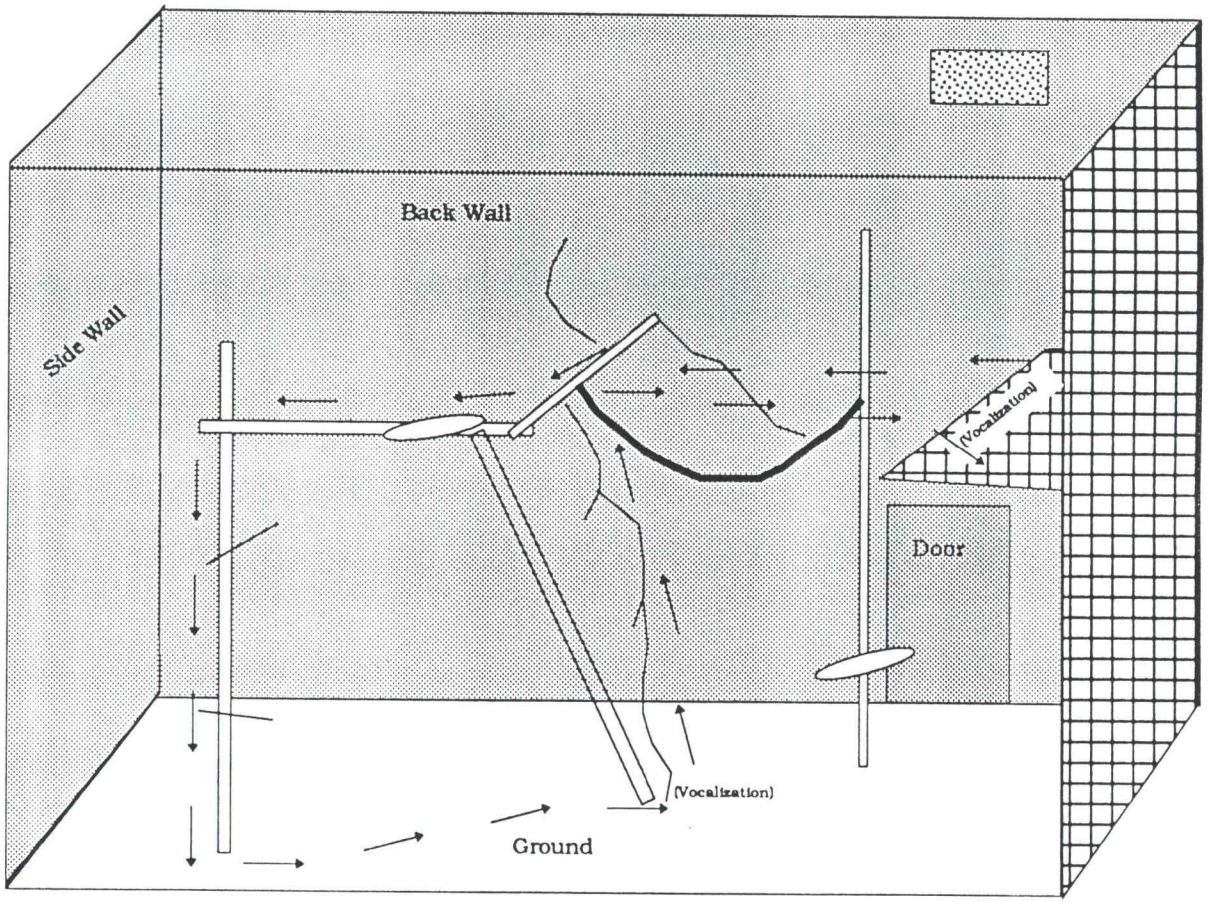

Figure 34 Schematic representation of the stereotypic behavior occured in Washington Park zoo

2.6 seconds and the frequency range was between 0 kHz and 2.75 kHz (Figure 35). The calls were uttered singly or in regular or irregular multiples of three to four.

PSV 1 vocalization was uttered only by the adult male prior to feeding. In one case during the vocalization, he circled around the enclosure two times and repeated the vocalization. On some occasions, PSV 1 vocalizations were followed by whoop calls. PSV 1 vocalizations were also uttered after seeing the zookeeper passing by during feeding hours. The facial expressions during vocalization include retracted cheek muscles, partially closed eyes, showing of teeth, and the mouth half open.

PSV 2

This vocalization was a long and broadly spaced frequency modulated harmonic unit. The frequency range varied between 0 and 0.5 kHz (Figure 36). The energy concentration was in the first harmonic. The utterance was repeated regularly or irregularly singly or in multiples of two to three.

PSV 2 vocalizations were uttered only by the adult female. The call was similar to deep squeals but the duration was long. Stereotypic behaviors such as jumping and circling the enclosure were followed by the vocalization. The duration of the vocalization varied from 1 second (during the early hours i.e., 12.05 PM to 12:30 PM) to 4 seconds (during late hours i.e., 12:45 PM to 1:30 PM). The facial expressions included protruded check and lips, open eyes and partially opened mouth.

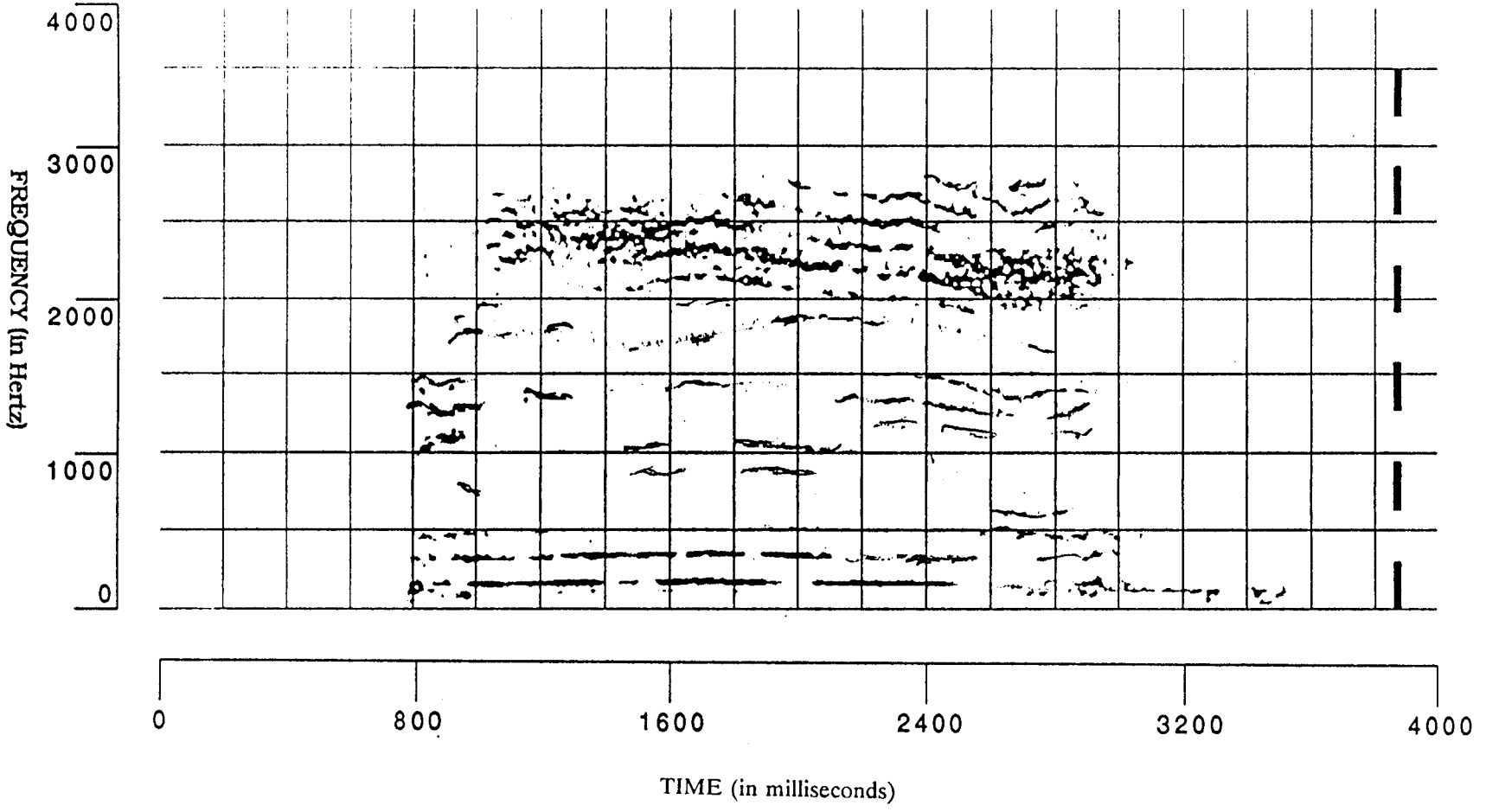

Figure 35 Spectrogram of PSV 1

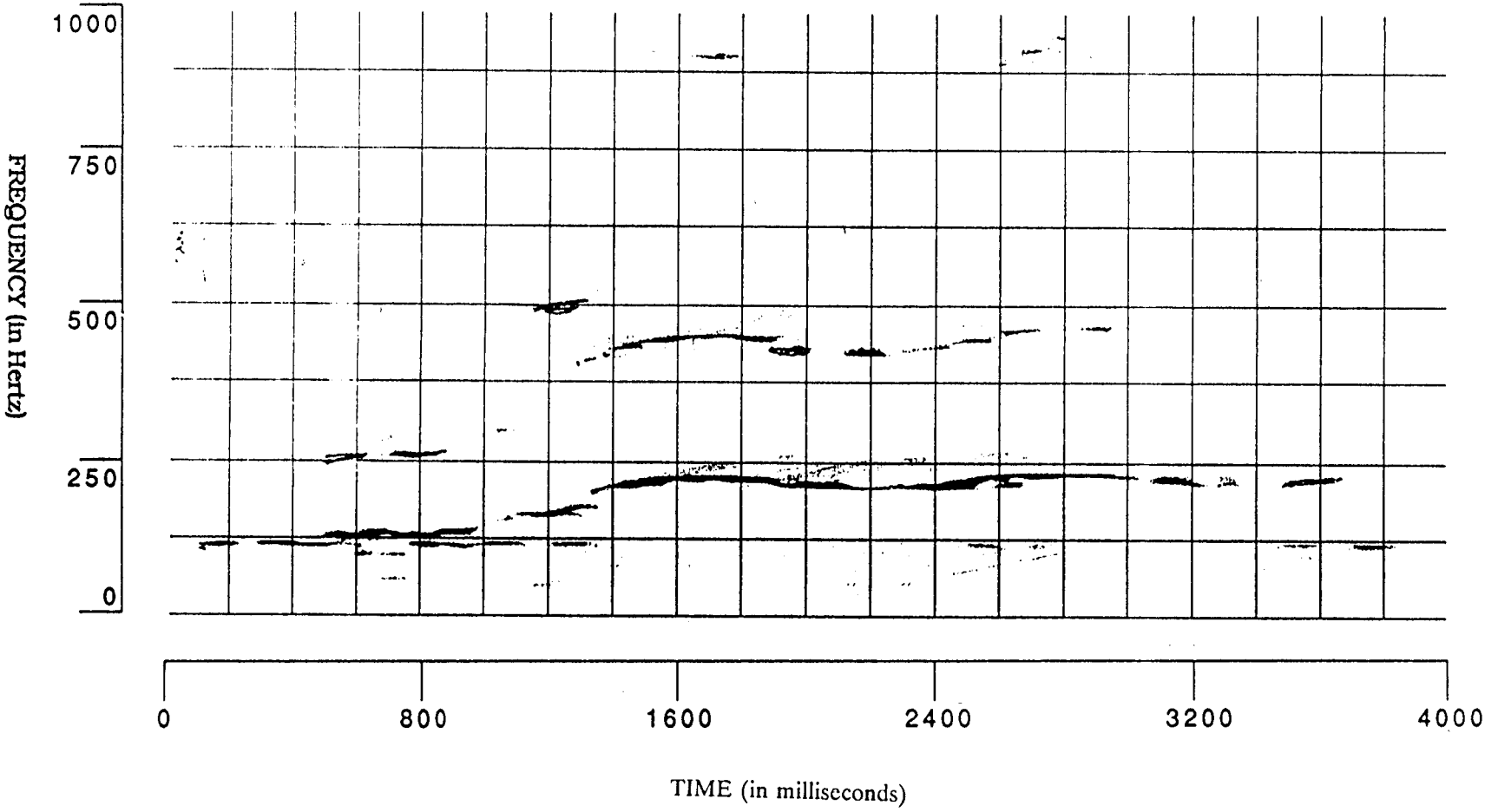

Figure 36 Spectrogram of PSV 2

PSV 3

PSV 3 vocalization was a long closely packed and irregularly modulated frequency. The call was composed of both tonal and non-tonal components. The initial phase of the vocalization was a non-tonal component with low frequency (2.7 kHz to 2.9 kHz) and increased to high frequency (4.3 kHz to 4.9 kHz). The frequency range was between 1.75 and 5 kHz (Figure 37).

This call was uttered by the adult female at the Metro Washington Park Zoo and by a subadult female at the San Diego Zoo. The calls were uttered just before feeding and were followed by the contact greet vocalization. At Metro Washington Park Zoo, PSV 3 vocalization uttered by the adult female induced the adult male to vocalize whoop calls and stereotypic behaviors similar to PSV 1 and PSV 2.

The PSV 3 vocalizations at San Diego Zoo were uttered soon after seeing the zookeeper with the food. No stereotypic behavior was observed.

The duration of the calls recorded at San Diego Zoo was less than 2 seconds, whereas the calls recorded at the Metro Washington Park Zoo exceeded 4 seconds.

Non-Vocal Sounds

The following non-vocal sounds occurred as a physiological response. No behavioral change was noted during each occurrence.

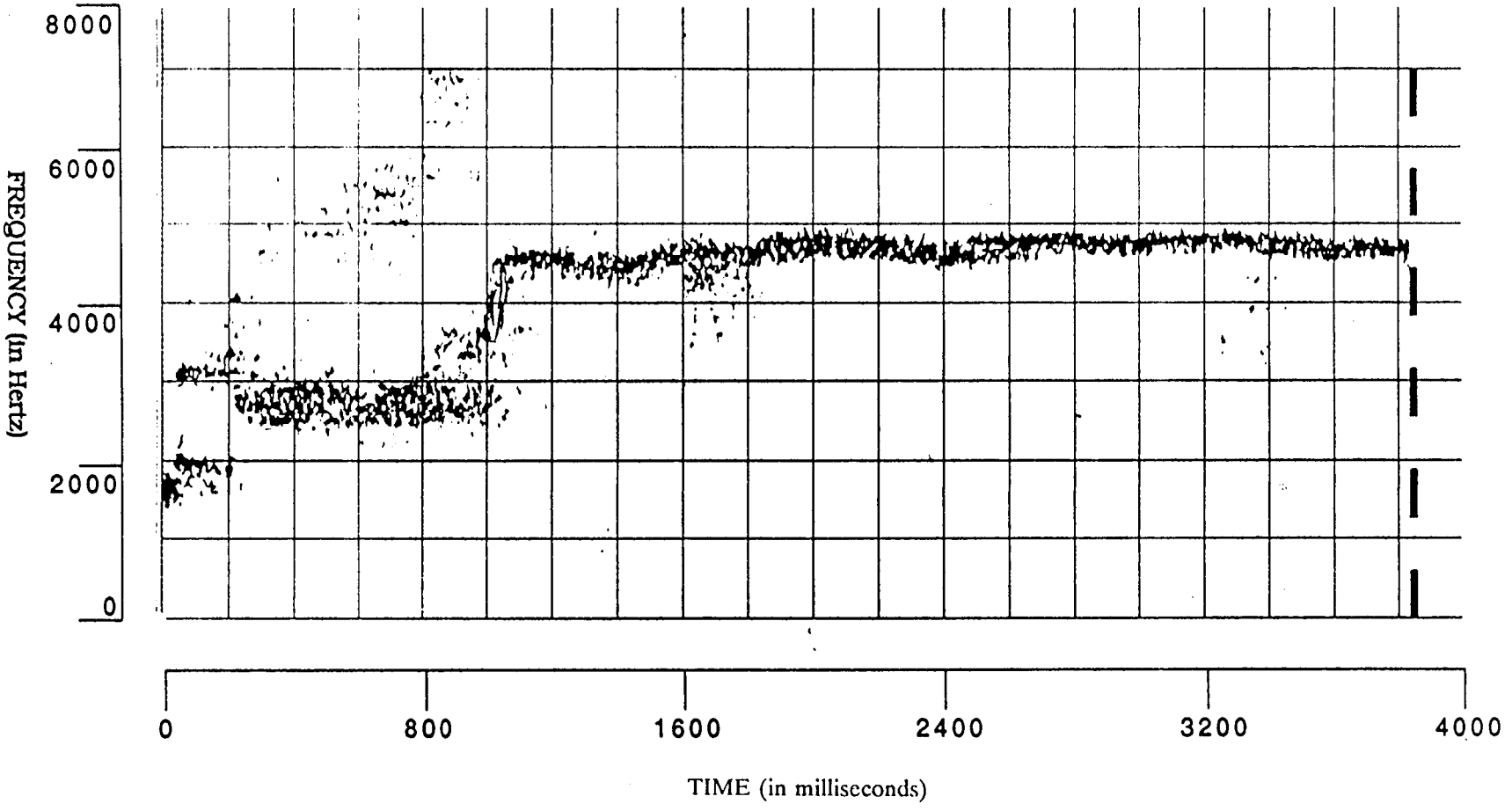

Figure 37 Spectrogram of PSV 3

Cough

Cough sounds were recorded from subadult males and adult females. During the occurrence, the individuals were seen inserting the fingers into the mouth and presumably cleaning the mouth. Coughs occurred during the early morning hours and afternoon feeding hours. The duration of the cough was short and was repeated irregularly up to four times.

Yawn

Yawns were recorded by the adult male and females. During the yawn, the cheek muscles were retracted, the mouth was completely open, the canine visible and the eyes were closed. Yawns were recorded during the early morning hours, afternoon and the early evening hours.

Sneeze

Sneezing was recorded from all the individuals except infants. Various body postures were observed during the sneeze. They include standing, sitting and walking. The animals were seen pausing a few seconds after sneezing and a slight body jerk occurred.

Belch

Belch sounds were recorded from all the individuals except juveniles and infants. The sound was similar to the low cough. In close encounters during the belch, a foul smell was sensed.

Vocalization Patterns During Translocation Operation

On August 7, 1990, two François' langurs, an adult female (mother) and an infant were translocated to the Riverside Zoo, South Carolina. Removal of the animals from the enclosure started around 1821 hrs and lasted until 1847 hrs. Behavioral observations and vocalization recordings were carried out before, during and after the translocation operation to record any uncommon vocalizations that might occur during the operation.

The individuals were isolated to a separate enclosure adjacent to the bedroom where all the other individuals were kept for three days before the actual translocation operation. The two individuals had no access to the outdoor enclosures and had no physical contact with other individuals of the group.

The animals were brought to the transfer chamber where they were forcibly moved to a wooden crate. Later they were shipped in the same crate.

Several vocalization types occurred among the total population of langurs during the translocation operation. They were: threat scream by the adult female that was being later transported to Riverside Zoo, threat cough by adult male and females, bark by subadult males, low cough by adult females, subadult males and

females, whoop by adult females, contact greet and grunt by all the individuals except juveniles and infants. Among the vocalizations, only the low cough was unique to the translocation operation, and was not recorded during any other time of study at both Zoos.

The transported adult female uttered a threat scream followed by threat coughs facing the zookeepers during the transfer operation. Bark vocalizations were uttered by the mother during the separation of the mother and the infant from the holding area to the wooden crate. Whoop vocalizations were uttered by other adult females when the mother and infant were seen being transferred from the holding area to the wooden crate. Grunt vocalizations were followed by a whoop when the two individuals were forced to the wooden crate. The mother emitted threat screams aimed at the zookeeper.

Soon after the separation of the mother and infant from the holding area, the entrance to the holding area was opened enabling other individuals to have access. Within a few minutes, all the individuals came and inspected the enclosure cautiously walking and sniffing the area where the mother and the infant were kept. Adult and subadult females were seen urinating in the area after sniffing. Adult females uttered low coughs just before entering the holding area followed by the contact greet. All the individuals were seen feeding on the leftover food in the holding area and continued to stay there until dark.

Table 4 Summary of vocalization types of *Presbytis françoisi*

Type of Vocalization	Total number of vocalizations recorded	Vocal emitter	Context	Frequency Range (in kHz)	Duration (in seconds)
Alarm call	3	AF, SM	Predator in close proximity	1.5-1.75	0.325
Alarm bark	14	AM, AF, SM, SF, J	Appreance of a predator	0-2	0.1
Threat cough	397	AM, AF, SM, SF	Associated with fight/disturbance	0-8	1.0
Low cough	9	AF, SM, SF	During tension in the group	1.0-4.5	0.1-0.3
Bark	206	AM, AF, SM, SF, J	During play fight	1.5-6.5	0.45
Whoop	117	AM, AF, SM, SF, J	Pre-feeding hours/contact call	0-1.3	1.2
Contact greet	589	AM, AF, SM, SF, J	When establishing physical contact	0-14	0.5-0.8
Threat scream	113	AF, SM, SF, J	During agonistic interactions	0.5-13.5	2.8
Grunt	23	AM, AF, SM, SF	During agonistic interactions	0-8	0.15
Squeak	19	SM, J	Defensive vocalization	2-9	0.4
Squeal	394	SM, SF, J	Play fights	0-16	4.0
Play scream	684	AM, AF, SM, SF, J	During play	0.8-12.0	3.2

contd.,

Table 4 contd.,

Type of Vocalization	Total number of vocalizations recorded	Vocal emitter	Context	Frequency Range (in kHz)	Duration (in seconds)
Screech	189	AF	Agonistic interactions	0.5-13	0.35
Aaoo**	4	SF	Unable to determine	1.25-2.5	0.7
Cry**	58	I	Rough handling of infant	0.75-6	4.7
Qua**	116	I	During allomothering	0.2-10	1.5
Whistle**	137	I	Rough handling/pain	0.5-13	16
Weaning screem**	32	I	Loss of physical contact	0.5-15.5	0.2
Weaning squeal**	9	I	During nursing	0.2-12	1.1
Loud call**	-	AM	In response to external noise	Unknown	Unknown
PSV 1*	68	AM	Prefeeding/stress	0-2.75	2.6
PSV 2*	51	AF	Prefeeding/stress	0.-0.5	4.0
PSV 3	471	AF, SF	Prefeeding/stress	1.75-5	5.5

* occured only at the Metro Washington Park zoo ** occured only at the San Diego zoo
A= Adult, S =sub adult, J =juvenile, M =male, F =female, I= infant

Summary

The vocalization patterns of captive François' langurs, *P. francoisi*, are classified in two categories. Type I includes 20 different vocalization patterns. Type II consists of three different patterns associated with stereotypy and possible stress under captive conditions. Spectrograms are given for all the call types except loud call. For each call type, age and sex of the emitter, behavioral context and the physical characteristics of the vocalization are described. Among the vocalizations recorded, the infant whistle was the longest in duration. A brief description of responses by the mother to the playback of the infant cry vocalization is also given.

4. DISCUSSION

Behavioral and spectrographic analysis of the vocal repertoire of captive François' langurs *Presbytis francoisi* revealed 20 different patterns in addition to the three stress induced vocalizations. For each vocalization, spectral characteristics such as frequency modulation, harmonics, tonal and non-tonal components are described.

Among the vocalizations recorded, adult males uttered eight different vocalizations under the Type I and one under the Type II category. Adult females uttered 11 vocalizations under Type I and two under Type II. The subadults of both sexes uttered 13 different call types in Type I and one under Type II.

Most of the vocalization patterns recorded were cause-specific. The alarm calls occurred three times during the course of study: twice for a domestic cat and once for an unknown bird. During each occasion, the call was uttered only once.

The behaviors associated with the alarm calls, such as alertness and silence, are common among many species of primates. The alarm calls given by other species of captive primates also brought alertness among *P. francoisi*. The langurs respond to calls such as whoop, threat bark and alarm, by ceasing the activity for a short duration and closely inspecting the surroundings. According to one of the zookeepers at the San Diego Zoo, the alarm call given by ruffed lemur (*Varecia variegata*) also alerts the *P. francoisi*.

Species specific alarm calls have been described in other species of *Presbytis* and sharing of alarm calls by sympatric species has been observed among *P. entellus* and chital deer *Axis axis* (Newton 1989). During the study, alarm calls were uttered when still photographs of different animals such as leopard, snake and salamander were shown. The calls suggested the presence of species specific predatory vocalizations among François' langurs, as vocal responses to individual photographs were acoustically different. Further field studies are required to examine the behavioral responses and vocalizations among *P. francoisi* under such conditions.

Whoop calls in many langurs and macaques are emitted as contact calls and they are given in close proximity (Hohmann and Herzog 1985). However, the function of whoop calls of captive *P. francoisi* is not clear from the study.

The frequently uttered vocalizations by adult females, subadult males, and females, during and after fights include the threat cough, contact greet, grunt and squeal. The common vocalizations occurring during play were squeals, squeaks and play screams.

Greeting calls accompanying behaviors such as embracing, grooming and mating occur among many species of primates. Among colobines, the contact greet call has been recorded in *P. johnii* and *P. entellus* (Hohmann 1989a).

Contact greet vocalizations were uttered by the *P. francoisi* during agonistic interaction, play and allomothering behavior. In the case of agonistic interactions, threat calls were preceded by greeting calls with submissive expressions and

squeals or screams. Behaviors associated with contact greet served as a buffer during agonistic interactions, leading the participants to stop aggression. During allomothering behavior, subadult males and females snatched the infant from the mother on various occasions. One such instance was when one of the adult females chased the subadult male to retrieve the infant. In response to the chase, the subadult male left the infant on the ground and emitted squeals followed by a series of greeting calls, presumably an act of reassurance. On some occasions, a grimace was accompanied with squeals.

Loud calls occur in many species of colobines and cercopithecines (Gautier and Gautier 1977). Among colobines, loud calls have been reported by many field studies (Hohmann 1989a, 1989b, 1990; Herzog and Hohmann 1984; Tenaza 1989 and Wilson and Wilson 1976). According to Curtin (1980) and Tenaza (1989), the loud calls were exclusively produced by the dominant male. Tenaza (1989) stated that the loud calls were given in response to falling trees, thunder and other sudden loud noises. In the case of *P. francoisi*, loud calls occurred under similar conditions such as noise generated by disposal trucks. Hence, it is assumed that such noises agitate the adult male to give a series of loud calls.

Among the genus *Presbytis*, varying degrees of age-specific vocalizations have been observed in *P. entellus* and *P. johnii* (Hohmann 1989a, 1991). The studies of *P. francoisi* indicated the presence of four different vocalizations among infants, which were not uttered by any other individuals, thereby suggesting the presence of age-specific vocalizations. It is assumed that calls uttered by infants

such as weaning squeals and weaning screams may not be present when the individual reaches maturity and adulthood.

In captive primates, stereotypy and abnormal behaviors such as clinging, inappropriate mounting, thumb suckling and eye closing have been observed (Suomi 1982). Under stressful conditions age-inappropriate clinging behavior has been observed among rhesus monkeys *Macaca mulatta* (Suomi 1979). However, I know of no reports of stress induced vocalizations among captive langurs.

The stereotypic behavior and PSV vocalizations exhibited by *P. francoisi* in this study occurred mainly at the Metro Washington Park Zoo and only during pre-feeding hours. Among the three vocalizations, PSV 3 occurred more frequently than the other two vocalization types. The frequency of utterance of PSV 3 vocalizations was higher in the Washington Park Zoo than at the San Diego Zoo.

According to the observations, the long span of feeding time initiated PSV vocalizations and the feeding time varied considerably at both the Zoos. Hence, it is postulated that such behaviors and vocalizations can be reduced or eliminated by providing food earlier during the day, rather than between 12:00 noon and 1:30 PM, as was the procedure in the study period.

Other reasons for the occurrence of PSV vocalizations in the Metro Washington Park Zoo may include the small number of langurs (two individuals) and the small total area of the enclosure. On the other hand, the San Diego Zoo had a more semi-natural environment than the Washington Park Zoo and had 13 individuals (Figure 9). PSV vocalizations may be reduced or eliminated by feeding

the langurs frequently, or earlier during the day. Introducing play objects may also help reduce the stress among the langurs. Making the enclosure bigger and more natural may also help reduce the stress caused under captivity.

Allomothering Behavior

Between August 5th and August 9th 1990, allomothering behavior (also called aunting, alloparenting, and infant transfer behavior) was observed among *P. francoisi* at the San Diego Zoo. Behaviors and vocalizations occurring during the first five days of birth of an infant were recorded.

Among Colobinae, infant transfer has been observed in all species of *Presbytis* (Kohda 1985). Infant transfer is known to occur during the first day of life (Jay 1965; Poirier 1970 and Bennett 1988) and the mother has a limited control over the infant transfers (Jay 1965 and Bennett 1988). Individuals who carry infants, regardless of their sex and relationship to the mothers, are commonly referred as aunts.

During the study, the daily activity pattern of the group was concentrated around the infant and the mother. All the individuals in the group (except the adult male) were engaged in allomothering behavior. Allomothering behavior includes cuddling, embracing the mother and the infant, grooming, kissing the head and the mouth, carrying and protecting the infant and establishing physical contact.

The mother was tolerant of allomothering behavior on most occasions. Grooming of the infant by aunts involved different regions such as head, body,

anal region and tail. Play involved adult females, subadult males and females and juveniles. They included pulling the tail of the infant, snatching the infant from the mother and from other aunts, and abandoning the infant during the middle of a chase. During infant transfers, subadult males and females handed over the infant passively to the mother.

Cooperative behavior during aunting was also observed. On several occasions, the mother handed over the infant to one of the adult females while feeding.

Several vocalizations associated with the behavior were recorded during this period. Apart from the vocalizations uttered by infants, other vocalizations that occurred during allomothering were grunts, screams, squeals, and threat barks. Infant retrieval by the mother from subadults included chase and agonistic interactions. The mother attempted to retrieve the infant when there were threat screams or squeals among two aunts trying to transfer the infant. During such occasions, the mother came and forcefully retrieved the infant. The mother was seen engaged in fights with subadult males and females while they were attempting to pull the infant with the tail. The mother was tolerant when squeals were uttered by the infant.

The contact greet was given by all the individuals (except adult male and juveniles), while hugging the mother and the infant. On most occasions after the contact greet, the subadult males and females and juveniles were successful in retrieving the infant from the mother and moving to an isolated place. On certain

occasions, the juveniles were pushed away by the mother and by other aunts when retrieving the infant. Under such conditions, the juveniles uttered squeals, presumably as a submissive gesture.

Vocalizations were also uttered by the infant when the mother was grooming the infant. While grooming, the mother was seen lifting the infant by its tail and preventing it from moving away. On two occasions, the infant was retrieved by the mother during alarm bark and alarm calls. During sleeping, the mother and the infant were surrounded by the aunts (Figure 38).

Some authors suggest that allomothering behavior is a learning behavior for females who need to develop maternal skills (Lancaster 1971). Others (McKenna 1982) consider allomothering in *P. entellus*, who share their extremely young infants during care giving, as the most permissive behavior in all colobines. Subadults may possibly learn the skills of parenting during aunting behavior. The presence of an infant in a group may induce group activity such as play fight for handling young, allomothering behavior and other activities and may bring group cohesiveness.

Comparison of Vocalization Patterns with Other Species of Colobinae

Comparison of vocalization patterns and behavior of *P. francoisi* with other species of colobines revealed many similarities in behavior among other species of *Presbytis*.

Figure 38 Mother and infant surrounded by aunts

Behavioral comparison of the contact greet in different species of primates indicated many similar behaviors. Among many species, contact greets accompany different behaviors such as face to face running, and hugging, mating and grooming. Similar behaviors occurred among *P. francoisi*.

The whoop calls in *P. entellus* are very similar in sound and acoustic structures to that of *P. francoisi*. The harmonic frequency range of whoop calls in *P. entellus* is between 0 and 1 kHz (Vogal 1973), which is similar to that of *P. francoisi*. At the Metro Washington Park Zoo, utterance of the calls was confirmed only after seeing the face of the emitter, as *P. entellus* and *P. francoisi* were housed adjacent to each other. On some occasions, the utterance of the whoop calls by a *P. entellus* langur initiated a *P. francoisi* to emit whoop calls.

Play vocalizations occur in both old world and new world primates. According to Masataka and Kohda (1988), specific play vocalizations are produced exclusively by certain species of primates in which allomothering behavior occurs. Among Colobines, play vocalizations have been observed in *P. cristatus*, *P. entellus*, *P. johnii* (Masataka and Kohda, 1988) and *P. thomasi* (Kunkun, 1986). The play vocalizations uttered by François' langurs include squeals, play scream, and contact greet. Both allomothering and play vocalizations among *P. francoisi* suggest that it may be common among the genus *Presbytis*.

On many occasions *P. francoisi* observed play between the groups of Douc langurs *Pygathrix nemaeus* (at the San Diego Zoo) and *P. entellus* (at the

Washington Park Zoo). Only subadults and juveniles were seen playing by uttering calls such as squeals, play screams and squeaks.

Among the vocalization studies of *Presbytis*, this is the only known report on the presence of the stress induced vocalization (PSVs) among captive langurs. The study also indicated the presence of the low cough, which is unique to *P. francoisi*.

Need for Further Field Studies

François' langurs are one of the least studied primates in the genus Presbytis. Their habitat, ecology and behavior has not been studied in the wild. As the data on vocalization for this study were gathered under captive conditions, the following recommendations are offered to go beyond the present study.

a. Visual communications may be specific to the ecological conditions that François' langurs live in. As the habitat of this species is poorly known, use of vocalization and visual communications (if any) should be examined in the wild and in other captive enclosures.

b. Vocalizations involving seasonal mating patterns, oestrous cycle and intergroup aggression should be studied.

c. Further field studies are necessary to understand the use of contact calls such as whoop vocalizations, which may play an important role in their natural habitat.

d. Calls associated with territoriality, seasonal calls, mating and night calls (as noted in *P. melalophos* (Johns 1984)) should be checked from field studies, as such calls either do not occur or are rare under captive conditions.

e. Context specific calls such as calls associated with chasing should be further verified from the field studies.

f. The repetition of a certain type of vocalization may vary considerably in field conditions. For example, a predatory bird flying over the enclosure may have less effect on the captive langurs than in the wild condition.

g. Several behavioral responses to selective logging, possibly the stress caused due to deforestation and the loss of home range, have been observed among *P. melalophos* (Johns 1984). Such calls may be present among François' langurs in the wild, as similar conditions are present in their natural habitat (Ratajszczak et.al. 1990).

h. François' langurs demonstrated the presence of specific vocalizations when they were shown predatory photographs from a magazine. Presence of species specific vocalizations should be further examined from the field studies.

i. The alarm call and huddling after seeing the predator, and retrieval of infant by the mother during the alarm call and alarm bark vocalizations, have been described among François' langurs in this study. Further investigation is necessary in their natural habitat.

j. Further studies are necessary to evaluate the sharing of vocalizations by sympatric species, and these vocalizations should also be compared with other captive populations of the same species.

Conclusion

The following conclusions were drawn from the study of vocalization patterns among captive François' langurs *Presbytis francoisi*.

a. Vocalization among *P. francoisi* at two enclosures consists of 20 apparently natural patterns as well as three patterns related to stereotypy and possible stress under captive conditions.

b. Whistle vocalizations of the infant are of the longest duration.

c. Age-specific vocalizations were found among infants.

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APPENDIX

APPENDIX A

GLOSSARY OF TERMS

The following definitions are partially or completely extracted from various sources (duly acknowledged at the end of the glossary; other sources are cited in the references section), to provide more meaning to the terminologies used in the thesis. The descriptions should be taken only as working definitions as some may lack technical accuracy and precision.

DECIBELS

Refers to loudness; it simply means that a logarithmic power ratio is being used and unless referred to a specific measure, does not represent an absolute measurement.

DYNAMIC RANGE

Related to the signal-to-noise ratio, the dynamic range gives the range of amplitude variation that a device can accommodate at a given setting.

ENERGY CONCENTRATION

The darkest portion of the tracing on the spectrogram.

FREQUENCY

The number of times that any regularly repeated vibration occurs in a given unit of time.

FREQUENCY DISTRIBUTION

The distribution of frequency along the *y* axis.

FREQUENCY RANGE

The total range of the spread along the *y* axis including upper and lower frequency.

FREQUENCY RESPONSE

This is the degree of amplitude change with respect to frequency. This specification is usually presented graphically with amplitude on the *y* axis and frequency on the *x*.

FORMANTS

Frequency bands with amplitudes modulated by supraglottal resonances. The first formant (the lowest) is called F_1, the second F_2, and so on. F_0 (the fundamental frequency), F_1 and F_2 (the formants) are among the most important spectral parameters. Note that F_0 describes a physically different effect than F_1 and F_2.

FUNDAMENTAL FREQUENCY

The slowest frequency component of a harmonically oscillating system. The fundamental frequency (symbolized by F_0) is in almost all instances identical with the excitation frequency forcing the system to oscillate. The fundamental frequency is the frequency domain equivalent to the pitch period in the time domain.

HERTZ

It is the unit of measure of frequency, equivalent to one cycle per second, named after the German physicist Heinrich R. Hertz.

HARMONICS

Frequency bands that are integer multiples of the fundamental frequency. The fundamental frequency (F_0) is said to be the first harmonic. The frequency of the second harmonic is twice the F_0, the third harmonic is three times the F_0 etc.

MIXED UNITS

Units composed of both tonal and non-tonal sounds that are superimposed on one another are called mixed units. The tonal and non-tonal aspects are more or less separated by differences in frequency.

NON-TONAL UNIT

A non-tonal unit is composed of sound that is more or less continuously developed over a wide range of frequencies.

PITCH

Traditionally, the subjective correlate of frequency. The term pitch is often (inaccurately) taken as a synonym for fundamental frequency.

PHRASE

The phrase is a group of units that is separated from other similar groups by a time interval greater than any time interval separating the units within a phrase.

SIGNAL-TO-NOISE RATIO

Expressed in decibels, the signal-to-noise ratio is a measure of the distance between a reference level (usually the maximum capability) and the noise floor of the device. In many cases the specification is "weighted" according to a specific frequency curve. Ideally, an unweighed analysis is the more useful number for analysis as it is not a frequency-sensitive specification.

SPECTROGRAM

A spectrogram is an imprint in which sound is graphed in terms of the frequencies that are present in successive time intervals.

TONAL UNIT

A tonal unit is composed of sound characterized by one or more relatively narrow frequency bands. Units with a harmonic structure are included in this category.

UNIDIRECTIONAL MICROPHONE

A microphone which is directional in response.

UNIT

The unit is the basic element of the call, and is represented as a continuous tracing along the horizontal axis of the sonogram.

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