To the Graduate council:

I am submitting herewith a thesis written by Karen Lousie DeLuce entitled "Comparison of posture and substrate use in captive *Callithrix jacchus* and *Saguinus fuscicollis.*" I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Masters of Arts, with a major in Anthropology.

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Suzette D. Tardif, Major Profesor

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Comparison of posture and substrate use in captive *Callithrix jacchus* and *Saguinus fuscicollis* (Callitrichidae, Primates).

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee

Karen Louise DeLuce

August 1993.

DEDICATION

This thesis is dedicated to my late brother

Matthew Charles DeLuce

(1965-1982)

who taught me the value of life.

Thank You.

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ABSTRACT

This research attempts to determine if there are any differences in the amount of time captive *Callithrix jacchus*, *Saguinus fuscicollis* use various substrates. Following a literature review, the primary hypothesis posited is there may be a possible correlation between time spent on substrate and feeding patterns. Recorded observations at the Marmoset Research Center- University of Tennessee Medical Center will be analyzed with a non-parametric statistical test in order to test this hypothesis.

While this study shows no significant differences between the species in the time spent on substrates, a secondary observation reflects differences in postures between *Callithrix jacchus* and *Saguinus fuscicollis*. Factors which may have an effect upon the results of this study will be discussed.

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I. INTRODUCTION

Primate locomotion has been of interest to researchers for several decades. Recent studies on callitrichids indicate that there might be postural differences between tamarin and marmoset species. While both marmosets (*Callithrix*) and tamarins (*Saguinus*) share several morphological traits associated with posture and locomotion, there are other differences which may affect their movements. Observations in the wild (Garber, 1992) suggest that different callitrichid species occupy and utilize different niches within a given habitat. It is suspected that these differences may be observable in captive groups. *Callithrix* is expected to use larger vertical substrates more than *Saguinus*; the gum-feeding patterns of marmosets would require a larger amount of time spent on larger trunks of trees, while the fruit and insect diet of *Saguinus* would require more time on smaller, more diverse substrates.

The purpose of this thesis is to analyze and discuss differences in the locomotor and postural behaviors of two callitrichid species, *Callithrix jacchus* and *Saguinus* *fuscicollis*. Analyses of the two species' utilization of the vertical substrates in a captive environment will include examination of several possible factors which may contribute to inter-specific and intra-specific differences.

This thesis will analyze the amount of time each species utilizes vertical substrates of various sizes. If different substrate utilization is observed between both callitrichid species, how statistically significant are these differences? This analytical study will also examine differences within *Saguinus fuscicollis* and *Callithrix jacchus*; do the sexes differ in their utilization of the vertical substrates? There will be a discussion of factors which may influence substrate preference in callitrichids and other arboreal primates.

The study of postural behavior will also be included in this examination. Do these two platyrrhine species use different postures during vertical clinging and locomotion? I will discuss studies of morphological features, particularly on limb length, as factors in differing postures between the two species. As in the examination of vertical substrate usage, differences or similarites within the species will be focused on the sexes.

Prior to this analysis, a review of the literature is provided as a basis for the theoretical questions raised in this study. The review of this literature will familiarize the reader with the recent research on primate morphology and locomotion. The review concludes with recent advances in callitrichid research regarding positional behavior. While there have been a considerable number of morphometric and locomotion studies in primates, very little work has been done in postural behavior. This is particularly true in neo-tropical species. The utilization of arguments regarding basic primate traits, combined with more specific material on callitrichid locomotion and positional behavior, aids in the formulation of this study.

II. LITERATURE REVIEW.

The following section will summarize major studies accomplished in this field of research. The first section comments on general studies in regards to primate morphology and locomotion. This section is intended to familiarize the reader with recent advances in this field. The second section in this chapter discusses studies which are specifically concerned with *Callitrichidae*. This review will provide the reader with a basic understanding of recent trends in this area.

1. Primate Morphology and Locomotion-

The order *Primates* has been the focus of numerous morphological and structural studies for several decades (Clutton-Brock, 1985; Clutton-Brock and Harvey, 1979; Fleagle, 1985; Hildebrande et al, 1985; Hill, 1957; Jenkins, 1974, Jungers, 1985; Lewis, 1989). Much of the research is focused on the evolution of locomotor patterns and associated anatomical traits (Hildebrand et al., 1985; Jenkins 1974; Jungers, 1985; Lewis, 1989).

Researchers have long suggested that primates are "perfectly" adapted to arboreal life (Napier and Napier, 1967). They further speculate that other mammals which are conspicuously not like primates in morphology and behavior must be unsuitably adapted to arboreal life (Le Gros Clarke, 1959). This has led to the assumption that claws are maladaptive for swift arboreal locomotion (Campbell, 1966).

Cartmill (1974), however, argues that the clawed hands of squirrels are more adaptable than the grasping hands and feet of primates in several locomotor activities, such as clinging to or climbing on thick trunks or branches. Cartmill (1974) suggests that the prehensile feet and hands of primates are not "primitive retentions"; instead, they are highly specialized. Acquiescence by other researchers regarding the specialized limb morphology within the order *Primates* may be due, in part, to the large amount of variety observed within this order (Hershkovitz, 1977; Jungers, 1985; Lewis, 1989).

Because of the great variability observed in primate morphology, several researchers have suggested that the grasping hind foot is the only locomotor specialization characteristic of the entire order (Cartmill, 1974;

Fleagle, 1985). Adaptations by wholly arboreal primates will vary significantly from those of primarily terrestrial species.

Baba's (1989) osteometric comparison of primates within cursorial and graviportal groups reflects the expansive variation in locomotor capabilities. Baba suggests that body structures are influenced not by the habitat of an animal but by the mode of locomotion which is crucial for it's survival. However, the ecological niche occupied by an animal species, including *primates*, is an important factor in the development of positional behaviors.

Arboreal mammals encounter different risks than do primarily terrestrial animals. An arboreal environment will favor the development of behaviors and morphology which will minimize an animal's chance of falling. Cartmill (1985) suggests that each solution which an animal adopts to one specific problem posed by arboreal locomotion circumscribes its options in treating other ecological constraints. The convergence of evolution among tree-dwelling vertebrates is the result of the limited number of solutions available (Cartmill, 1985).

There are intraspecific as well as interspecific differences observed for all animals. Within the order *Primates* this is clearly observed. Primates occupy a broad variety of ecological niches; many species overlap with each other and in many cases compete for similar resources (Hershkovitz, 1977).

2. Callitrichid Ecology and Morphology-

The subfamily callitrichinae includes four genera of insectivorous primates which occupy a wide range of ecological niches from Panama through Brazil (Hershkovitz, 1977; Napier and Napier, 1986; Sussman and Kinzey, 1984; Rylands, 1989). Callitrichids occupy a geographical range from approximately nine degrees north latitude (in Panama) to roughly twenty-four degrees south latitude (Brazil, Bolivia). Altitudinal range is from sea level to approximately 1,400 meters above in the Brazilian highlands and 1,500 meters above in the Colombian Andes (Hershkovitz, 1977). Figure 2.1 presents a map reflecting the geographical distribution of callitrichids.

Callitrichinae are distinguished ecologically from other platyrrhine taxa by their "large branch feeding"

(Garber, 1992; Hershkovitz, 1977). Within the subfamily there is evidence of at least four distinct feeding patterns (Garber, 1992). These include:

1). Seasonal exudate feeding and occasional trunk foraging: this pattern has been observed in many of the *Saguinus* species.

2). Exploitation of bark surfaces, insects, and trunk utilization for the location of prey: this pattern is observed in *Saguinus fuscicollis*, and *Callimico*.

3). "Manipulative" foraging of bark-stripping for the location and consumption of concealed prey: this is observed in *Leontopithecus*.

4). Tree-gouging and year-long exudation: this is exhibited by *Callithrix*.

(Revised from Garber, 1992).

The subfamily *Callitrichinae* are morphologically unique among the new world monkeys, Platyrrhini, in several respects. Along with the closely related *Callimico*, callitrichines are considered the smallest of all living simian primates (Hershkovitz, 1977). The dental formula of callitrichines is unique among anthropoids; consisting of 2 incisors, 1 canine, 3 premolars, and 2

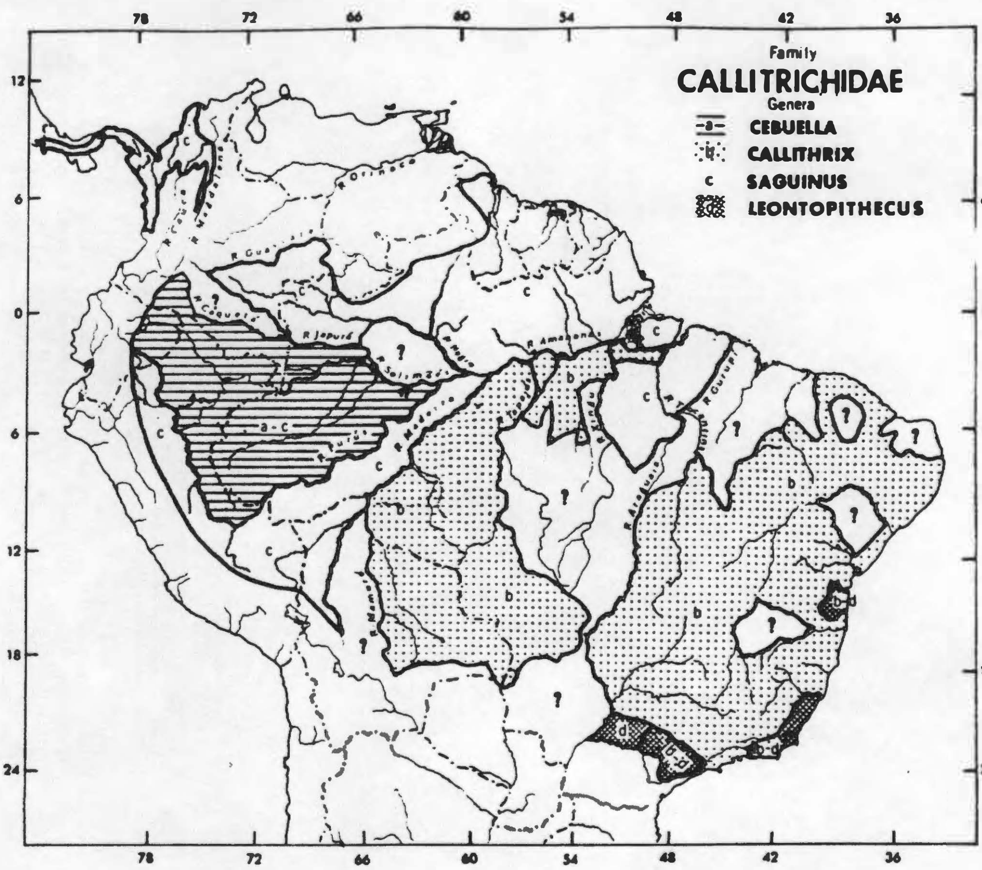


Figure 2.1 - Geographical distribution of Callitrichids
(From Hershkovitz, 1977).

molars per arcade for a total of 32 teeth. The mandible in *Callithrix* species is "V-shaped" and exhibits the so-called "short-tusked" condition in which the canines and the incisors are of equal length (Cole, 1986; Napier and Napier, 1986). *Saguinus* differs form *Callithrix* in that the mandible is "U-shaped" and the canines are longer than the incisors (long-tusked).

While the cheridia of callitrichids do share characteristics which place them apart from other primates, the origin of these traits is controversial (Hershkovitz, 1977; Ford, 1980). Both the hands and feet are pentadactylous, with the feet being extensively greater in length than the hand (Hershkovitz, 1977). As in all primates, the volar pads with frictional papillary ridges are present, with a "primitive" pattern of eleven total pads (Cartmill, 1985; Hershkovitz, 1977). Unlike other primates, callitrichids have sharply recurved claws on all digits except for the big toe. The claw of the hallux is expanded out into a transversely flattened nail overlying an enlarged apical pad (Cartmill, 1985; Hershkovitz, 1977).

Erikson (1963) classified *Callithrix* and *Saguinus* along with the smaller platyrrhines, *Aotus* and *Callicebus*, as "springers". Other researchers have classified callitrichids as quadrupedal with some vertical clinging and leaping (Napier and Napier, 1986). The movements of tamarins and marmosets have been equated to those of a squirrel. *Callithrix jacchus* and *Cebuella pygmaea* still retain the fast jerky movements which are characteristic of a primitive locomotor system (Hershkovitz, 1977; Napier and Napier, 1986). The movements of *Saguinus* species are similar but appear to be more "coordinated"; *Callimico*, despite their "tamarinlike" hands and feet, have a fluidity to their movements which closely resembles cebids (Hershkovitz, 1977). However, these contrasts in the coordination of callitrichids have not been observed by all researchers (Tardif, pers.com., 1993).

Ford (1980) suggests that callitrichid locomotor patterns may not be "primitive" as Hershkovitz suggests. Instead, they are derived characteristics of phyletic dwarfing. She suggests that a limitation of resources due to the formation of "island" habitats which were the result of normal disturbance of the neo-tropical environment and periods of increased aridity may have played some role in the dwarfing of callitrichids.

Recent morphometric studies indicate interspecific differences in the anatomical structure of limbs within callitrichids (Falsetti, 1986). Tamarins and marmosets differ from other new-world monkeys in their utilization of vertical substrates in clinging postures (Garber, 1992). Previous studies (Falsetti, 1986; Falsetti and Cole, 1992) have suggested differences which correlate to differential substrate preference. Research has demonstrated that invariable differences in the interspecific shape and size exist; researchers suggest that this reflects both phylogeny and positional behaviors related to differential substrate selection and utilization (Garber, 1970, 1992; Glassman, 1983; Moynihan, 1970).

In a comparative analysis of growth of the post-cranial skeleton of three callitrichid species; *Callithrix jacchus*, *Saguinus fuscicollis*, and *Saguinus oedipus*, Falsetti and Cole (1992) noted differential growth patterns. They suggest that a model of parallel allometry is best descriptive of the post-cranial growth of callitrichid skeletons. This implies that the patterns of growth-related change in shape vary slightly within each species and that these patterns preserve differences which are present at birth. These differences in ontogenetic growth may suggest differences in the adult forms of these callitrichid species. If the model of parallel allometry is correct then it is possible that this model might be applicable in adult forms.

These anatomical differences are associated with variations in the locomotor and positional behaviors of free-ranging populations. Studies on *Saguinus fuscicollis* suggest that with the increase in the lateral reach through forelimb elongation, this species could equally compete on both wide and narrow substrates (Falsetti and Cole, 1992).

Garber (1992), however, disagrees and argues that this anatomical feature is not specifically correlated to vertical clinging. Instead, it is associated with an increase in the distance required to stop observed in *Saguinus fuscicollis* during trunk to trunk leaps (Garber, 1992). This is supported by the evidence gathered through studies on wild populations. *Callithrix jacchus* spends a considerable amount of time clinging to and locomoting on large vertical supports while feeding on insects and exudates, yet it does not exhibit the extreme post-cranial morphology of *Saguinus fuscicollis* (Falsetti and Cole, 1992). The forelimbs of *Callithrix jacchus* are not enlongated as are those of *Saguinus fuscicollis*. There is scant information on the differences, if any, of the hindlimbs between these two species (Garber, 1992).

In correlation to callitrichid feeding patterns previously discussed, both arguments regarding forelimb elongation can be supported by the feeding pattern of *Saguinus fuscicollis*. With a diet consisting primarily of insects, there is a propensity to utilize a variety of substrates of varying sizes. This would correlate with Falsetti and Cole's (1992) suggestion that the increase in forelimb length allows for equal competition on small and large branches and trunks. However, Garber (1992) suggests that an increase in the length of the forelimbs aids in increasing the distance of leaps from trunk to trunk by sustaining most of the compressive load generated by impact. When hunting for insects and small invertebrates, there would be an increase in the amount of rapid movements between vertical substrates. Unlike exudate feeders, such as *Callithrix jacchus*, whose main food source is stationary, *Saguinus fuscicollis* must constantly search and hunt for their food.

The previous literature raises several questions concerning primate locomotion, particularly in callitrichids. Primates are considered "perfectly" adapted for an arboreal environment, yet there is a considerable amount of morphological and behavioral variation. Within platyrrhines, callitrichids have claws which are considered by some researchers as "primitive"; however, recent studies suggest that this characteristic may be a derived feature (Ford, 1980; Tardif, 1993). The morphological variation of limbs within calllitrichids has been correlated to positional behavior and posture; yet, there has been little research in a cross-analysis of tamarins and marmosets.

This examination of callitrichid positional behavior shall examine two species, *Callithrix jacchus* and *Saguinus fuscicollis*, in regards to their use of vertical substrates in a captive environment. This study will examine both species to see if there are any significant differences in the use of vertical substrates as is suggested by wild-population studies.

With the use of variably sized vertical substrates, this examination will attempt to locate preference between and within the species in a captive environment as has previously been suggested by other researchers. If differences do occur, morphological factors which have interested previous researchers will be examined to see if they have an effect on callitrichid positional behavior.

III. MATERIALS AND METHODS

This chapter includes descriptions of the subjects, study conditions, and the statistical analysis used in this study.

1. Introduction-

For this comparative analysis of callitrichid positional behavior, the Marmoset Research Center-University of Tennessee Medical Center facilities were used with the consent of Dr. Neal Clapp. The subjects were isolated from other animals in a separate room to prevent outside interference by other animals during the study. They were placed in the study enclosures the night before; this allowed the subjects to adjust to the difference of the environment.

The enclosures were two wire cages which were adjacent to each other (figure 3.1). The dimensions of each were thirty-six inches in depth, forty-eight inches in height, and thirty-six inches in width. Each enclosure was equipped with one horizontal and three vertical wood limbs that were placed in the same

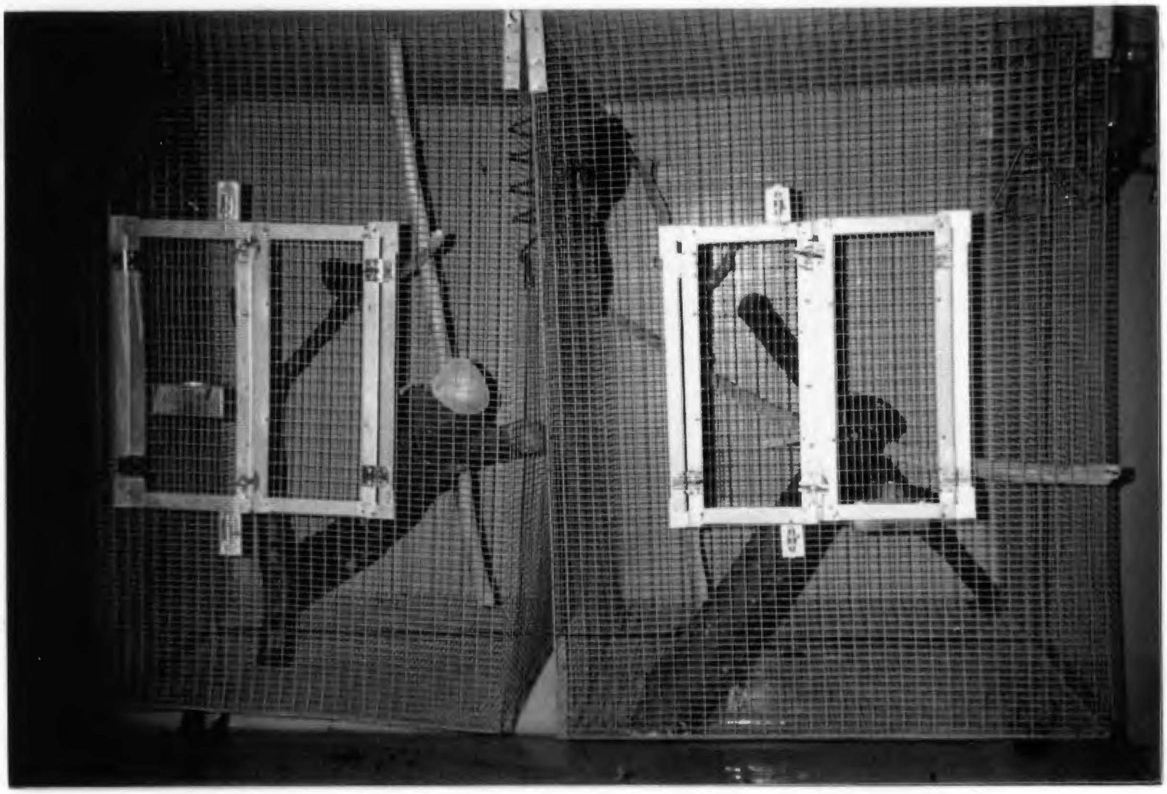


Figure 3.1 - Cages used in the study. They were placed side by side; in both substrates were placed in approximately the same positions to provide identical test situations.

positions in both cages to provide almost identical test situations for each species.

Since this study is concerned with the use of vertical substrates, the three wood limbs differed in size. The small substrate measured one and a half inches in diameter; the medium substrate measured two and a half inches in diameter; and the large substrate measured three and a half inches in diameter. The horizontal wood substrate was placed diagonally from the back left corner to the front right corner in both enclosures; it was located approximately in the center of each cage (figure 3.1).

The examination of positional behavior was conducted in two series of tests. In the first series of tests fruit-flavored yogurt was smeared onto the vertical substrates; this was done in an attempt to simulate natural feeding activity. In the second battery of tests, miniature marshmallows were used instead of the yogurt to entice the subjects onto the vertical substrates.

2. Subjects-

For this comparative analysis, two species of callitrichids were utilized; the tamarin species *Saguinus fuscicollis* and the marmoset species *Callithrix jacchus*. Eight individuals of *Saguinus fuscicollis* and ten individuals of *Callithrix jacchus* were used in this study. In an attempt to reduce any differences which may be influenced by the sex of an animal, equal numbers of adult males and females were used in each species. All of the subjects examined were healthy with no ailments or diseases, such as soft bone disease, which might have an impact on the data. One of the male *Callithrix jacchus* had shortened forelimbs; however, it was determined that since the difference in length was minimal this condition would not have a considerable impact on the study.

III. Observational Methods-

An event sampling technique based on Altmann's (1974) methodological criteria was used for this study. This included the recording of all locomotor and postural behaviors exhibited by the subject. The definition of behaviors recorded in this study are listed in table 3.1. During each twenty-minute period, all movements of the subject were recorded including the amount of time, in seconds, each subject spent on a substrate. The time results were then tabulated in each substrate category (table 3.2) for each subject.

Observations were recorded using a tape recorder and a stopwatch; the observer was located behind a blind approximately three meters from the enclosure. Individuals of the same sex but different species were placed in the cages next to each other. Each individual was observed in two twenty-minute intervals; the total number of intervals for both species was equal to thirty-six periods. The total observational time was twelve hours.

IV. Analyses-

Two sets of tabulations were amassed for each subject. Each subject's movement was tabulated in minutes and seconds for each observational category.

Data on both the use of vertical substrates and

Table 3.1. - Definitions of behaviors utilized in study.

BEHAVIOR	DEFINITION
Horizontal locomotor=	Moving on horizontal substrate.
Horizontal still=	No movement on horizontal
Leaping=	All limbs are absent from any substrate.
Posture A=	The limbs are abducted from the sagittal plane, with elbow joints flexed approximately 45 degrees.
Posture B=	The limbs are adducted towards the sagittal plane.
Posture C=	Forelimbs are abducted while hindlimbs are adducted; this posture observed on bottom and horizontal substrates.
Vertical locomotor=	Moving on vertical substrate. Specify small, medium, or large.
Vertical still=	Not moving on vertical substrate. Specify small, medium, or large.
Wire-clinging=	On the wire sides of the enclosure.

Table 3.2. - Substrate categories used in tabulation of data.

SUBSTRATE	DEFINITION
Wire=	Includes wire sides of enclosure.
Food-cup=	The stainless-steel food-cup, which was located on the side of each enclosure.
Top=	On the top of the enclosure.
Bottom=	On the floor of the enclosure.
Small vertical=	The vertical substrate which measured 1 1/2 inches in diameter.
Medium vertical=	The vertical substrate which measured 2 1/2 inches in diameter.
Large vertical=	The vertical substrate which measured 3 1/2 inches in diameter.
Horizontal=	The substrate placed horizontally in the enclosure.

the postural behavior were analyzed using the Mann-Whitney-Wilcoxon non-parametric statistical method.

This non-parametric ranking test may serve as an alternative to the two-sample *t* test (Freund, 1988; Sokal and Rohlf, 1991). This test calculates a test statistic (W) which tests for significance of difference between the medians of two populations.

The series of statistical tests utilized were performed in the Minitab computer statistical package release 8 (Schaefer and Farber, 1992).

IV. RESULTS

The following section presents the results of this study, including the substrate use data and postural behavioral data by both *Saguinus fuscicollis* and *Callithrix jacchus*. Results were plotted based on species and on sexes within the species. The Mann-Whitney-Wilcoxon non-parametric statistical method was used to compare the time each species (and each sex within species) spent on each substrate type.

1. Use of substrates-

The two callitrichid species, *Callithrix jacchus* and *Saguinus fuscicollis*, did not differ significantly in the time spent on different substrates within a captive environment. Tables 4.1.1-4.1.4 list the amount of time each species spent on the different substrates; this table also includes the ranges and the median for each species. The majority of time was spent on the wire sides of the enclosures and on the horizontal substrate. The statistical analysis of the time spent on different substrates reflected no significant differences. The results of the Mann-Whitney-Wilcoxon tests are listed in table 4.2.

Table 4.1.1 - Time spent on different substrates (in seconds).
Species- *Callithrix jacchus*
Sex- Male

Wire-clinging	Food-cup	Top	Bottom	Vertical small	medium	large	Horizontal
1534	0	0	143	192	13	1	161
1576	0	0	35	10	12	27	481
2078	0	0	203	10	45	0	64
253	27	0	508	0	98	590	1044
1517	79	0	319	40	104	22	0

Table 4.1.2.- Time spent on different substrates (in seconds).
Species- *Callithrix jacchus*
Sex- Female

Wire-clinging	Food-cup	Top	Bottom	Vertical Small	Medium	Large	Horizontal
1387	0	60	180	0	0	240	190
1213	5	0	539	0	0	316	25
1758	0	0	98	7	271	9	103
1043	50	7	0	11	1	0	930
1160	65	0	0	277	126	107	637

Table 4.1.3.- Time spent on different substrates (in seconds).
Species- *Saguinus fuscicollis*
Sex- Male

Wire-clinging	Food-cup	Top	Bottom	Vertical			Horizontal
				Small	Medium	Large	
1412	27	4	397	52	32	75	347
1773	0	21	553	0	0	0	0
508	4	0	726	584	57	3	551
926	48	19	24	1	10	4	1399

Table 4.1.4.- Time spent on different substrates (in seconds).
Species- *Saguinus fuscicollis*
Sex- Female

Wire-clinging	Food-cup	Top	Bottom	Vertical			Horizontal
				Small	Medium	Large	
1607	0	23	100	60	60	0	120
1259	49	0	421	24	6	0	152
1277	10	0	553	111	62	1	240
2183	0	0	4	0	0	1	5

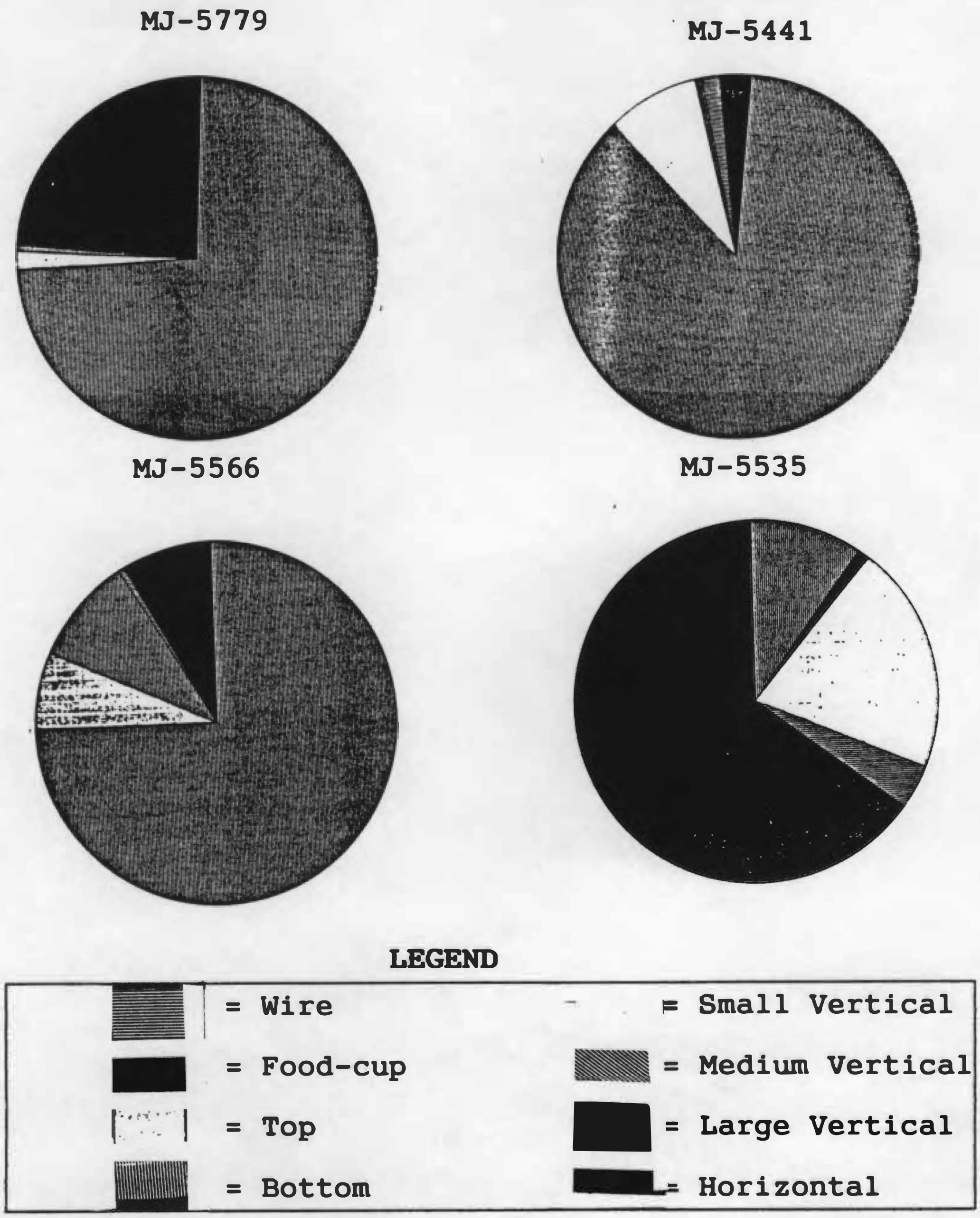
Table 4.2.- Mann-Whitney-Wilcoxon results for time on different substrates by each species. P= the probability of receiving a difference between the two medians. W= the sums of the ranks of the sums for both species.

	Callithrix jacchus		*Saguinus fuscicollis*		P-value	W
	# of subjects	Median	# of subjects	Median		
Wire	10	1452.0	8	1344.5	.8940	93.0
Food-cup	10	2.50	8	7.0	.9646	96.0
Top	10	0.00	8	2.0	.3508	84.0
Bottom	10	161.5	8	409.0	.2303	81.0
Small Vertical	10	10.0	8	3.0	.5636	88.0
Medium Vertical	10	29.0	8	21.0	.4501	104.0
Large Vertical	10	24.5	8	1.0	.0832	115.0
Horizontal	10	175.5	8	196.0	.9292	96.5

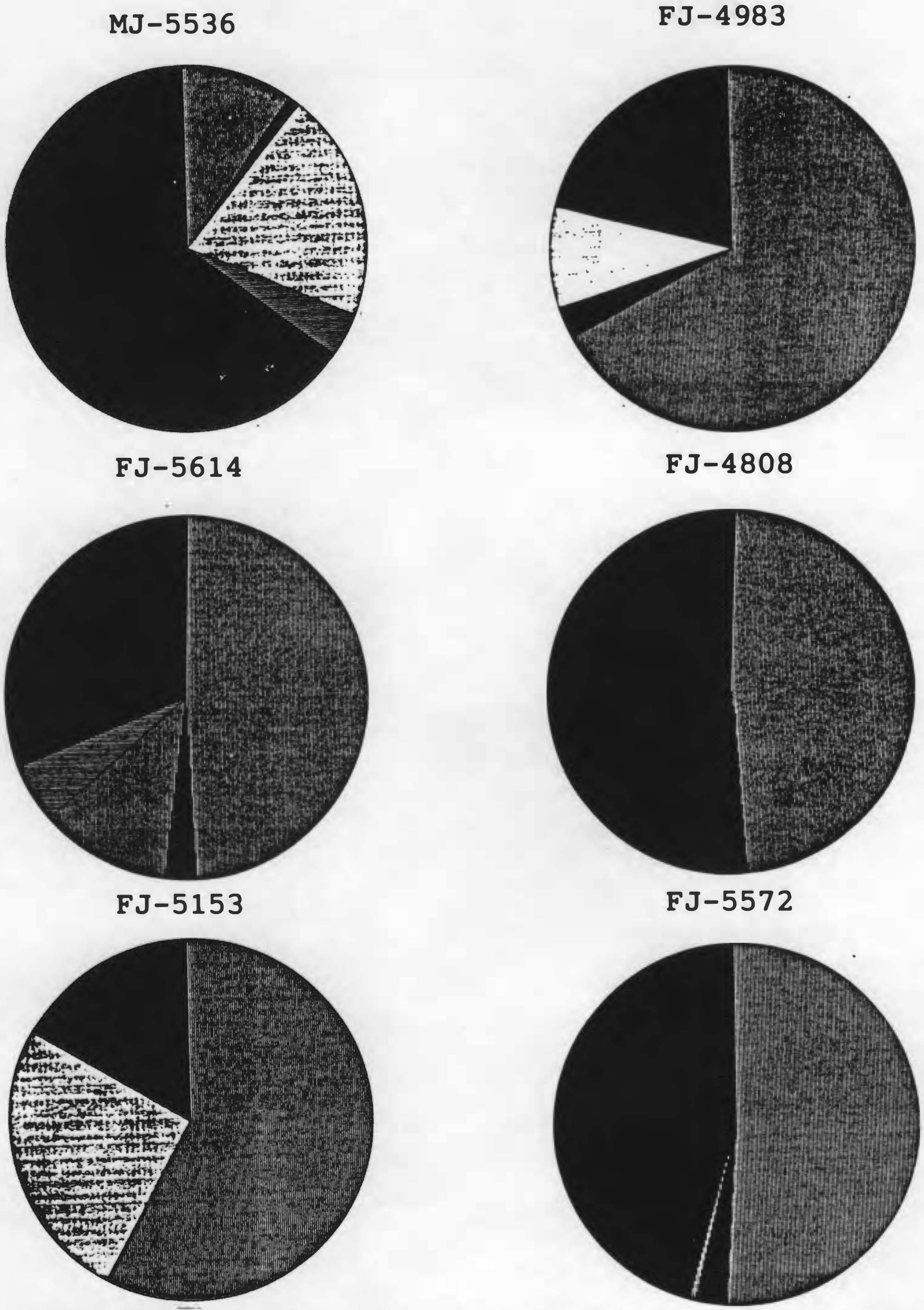
While none of the species differences were significant at $\alpha=0.05$, there were some differences which suggested possible trends. *Callithrix jacchus* tended to use the large vertical substrate more than *Saguinus fuscicollis* (p=.0832, table 4.2). Within each species, there was no significant differences between the sexes.

Comparison of pie charts (figures 4.1.1-4.1.18) reflects no substantial differences in the amount of time each species spent on the different substrates; however, some differences between individuals are clear. MJ-5535 spent 590 seconds on the large vertical substrate. When the ranges and medians were plotted on a bar chart (figure 4.2), *Callithrix jacchus* appeared to spend more time on the large vertical substrate than *Saguinus fuscicollis*.

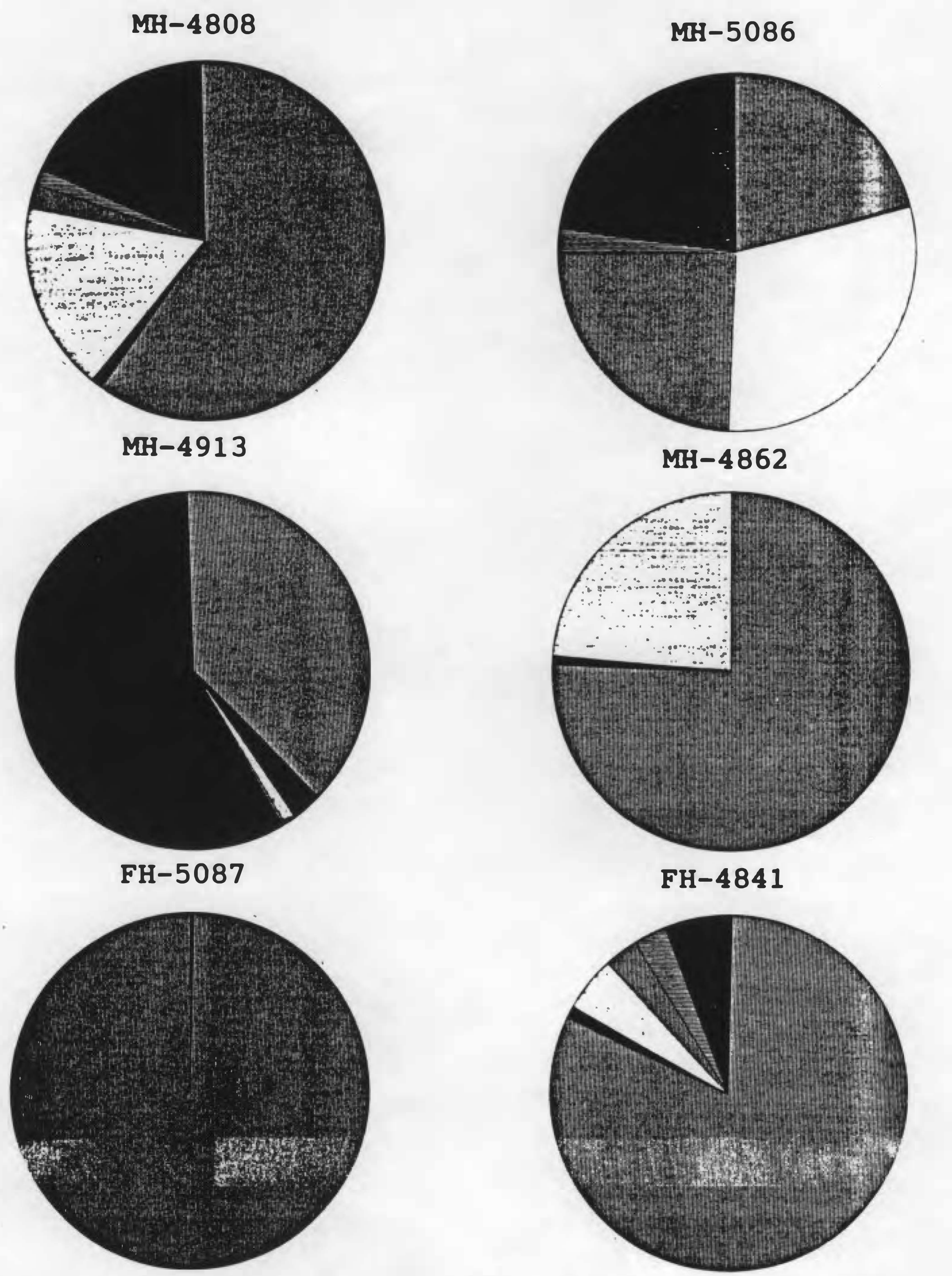
There appears to be a correlation between the subjects' familiarity with the study enclosure and the use of the vertical substrate. The animals were placed in the enclosures the previous afternoon, except for two *Callithrix jacchus* (MJ-5535, FJ-5626) and two *Saguinus fuscicollis* (MH-5086, FH-5197). These four subjects were placed in the cages on Friday afternoon and were observed the following Monday morning. Three of the four individuals used the vertical



Figures 4.1.1- 4.1.4 - Pie charts of time spent on different substrates by each individual.

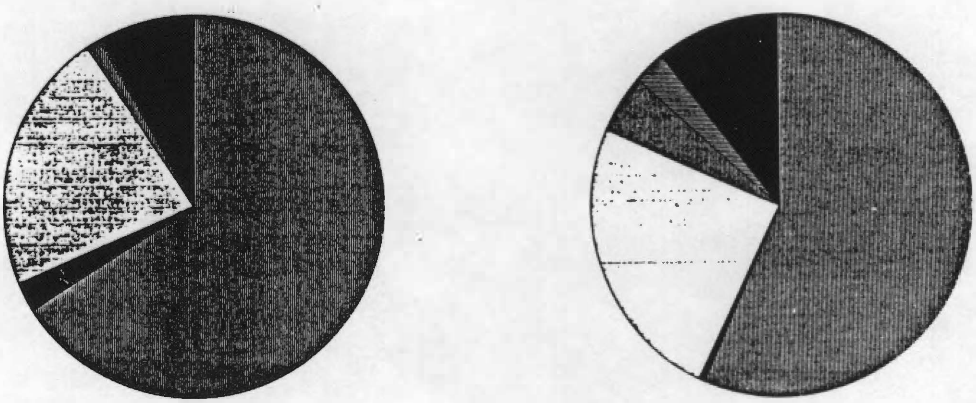


Figures 4.1.5- 4.1.10 - Pie charts of time spent on different substrates by each individual.



Figures 4.1.11- 4.1.16 - Pie charts of time spent on different substrates by each individual.

FH-4815 FH-5197



Figures 4.1.17- 4.1.18 - Pie charts of time spent on different substrates by each individual.

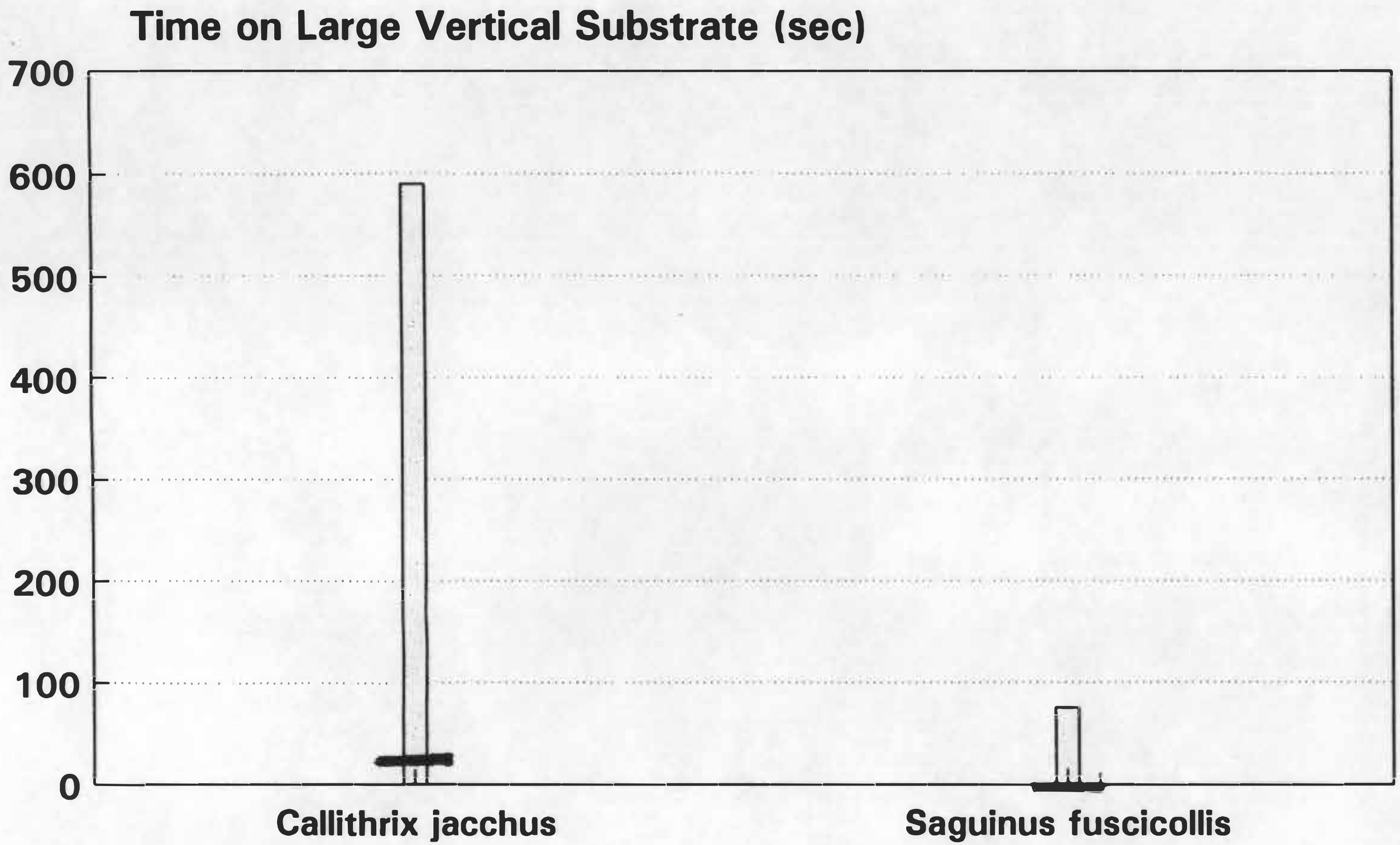


Figure 4.2. - Range of time spent on large vertical substrate by species. Horizontal line indicates median for both species.

substrates more than the other tamarins and marmosets in the study.

These results suggest that there is no difference between the common marmoset and the saddle-backed tamarin in the use of substrates. However, there may be other factors involved which may have affected the data.

2. Differences in posture-

While there were no significant differences observed in the time spent on different substrates by the two callitrichid species, there were substantial dissimilarities in the posture the species exhibited during this study (Table 4.3.) lists the exhibited postures, the total number of recorded positions, and the percentage of the total for each posture.

For posture A, in which there was an abduction of the limbs (approximately forty-five degrees) from the sagittal plane (figure 4.3), there was a significantly higher percentage of *Saguinus fuscicollis* adopting this posture than *Callithrix jacchus* ($p=0.0004$). The second observed

Tables 4.3.1- 4.3.4 -Postural data (including percentage). A= limbs are abducted from the sagittal plane with the elbows and knees flexed. B= limbs are adducted towards sagittal plane. C= forelimbs are abducted, while hindlimbs are adducted.

♂ *Callithrix jacchus*

I.D. Number	A	B	C	Total	%A	%B	%C
5779	9	62	1	72	12.5	86.1	1.39
5566	8	52	2	62	12.9	83.87	3.23
5535	4	71	4	79	5.06	89.87	3.23
5536	14	58	2	74	18.92	78.38	2.70
5441	3	91	4	98	3.06	92.86	4.08

♀ *Callithrix jacchus*

I.D. Number	A	B	C	Total	%A	%B	%C
5626	1	79	0	80	1.25	98.75	0.00
5572	1	58	8	67	1.49	86.57	11.94
5153	2	50	0	52	3.85	96.15	0.00
4983	2	65	0	67	2.99	97.02	0.00
5614	5	83	3	91	5.49	91.21	3.30

♂ *Saguinus fuscicollis*

I.D. NUMBER	A	B	C	Total	%A	%B	%C
4808	122	11	2	135	90.37	8.15	1.48
4862	136	11	0	147	92.52	7.48	0.00
4913	129	16	1	146	88.36	10.96	0.68
5086	109	9	2	120	90.83	7.50	1.67

♀ *Saguinus fuscicollis*

I.D. Number	A	B	C	Total	%A	%B	%C
5197	114	6	1	121	94.21	4.96	0.83
5087	95	21	1	117	81.20	17.95	0.85
4815	126	6	3	135	93.33	4.44	2.22
4841	114	12	1	127	89.76	9.45	0.79

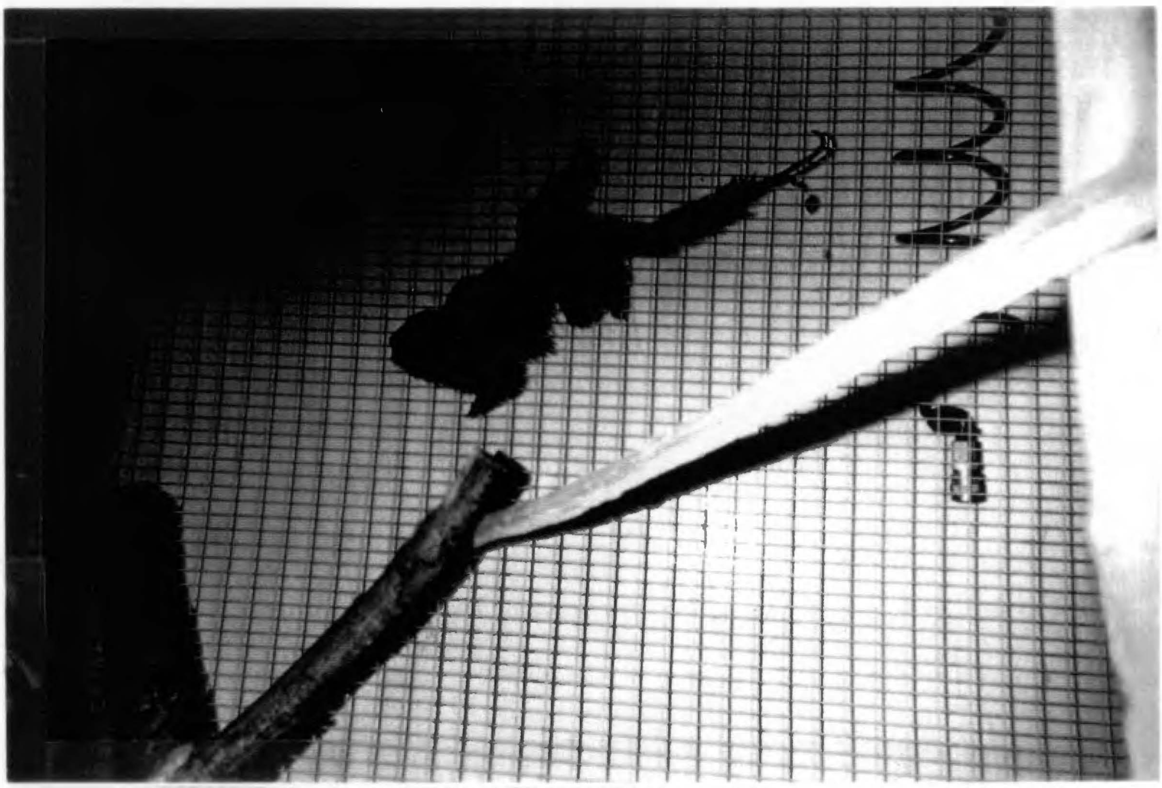


Figure 4.3 - Posture A exhibited by *Saguinus fuscicollis*. Limbs are abducted from the sagittal plane with the elbows and knees flexed.

posture (figure 4.4), in which there was an adduction of the limbs towards the sagittal plane, reflected a higher percentage of *Callithrix jacchus* utilizing this posture than *Saguinus fuscicollis* ($p=0.0004$). The results of the Mann-whitney statistical test for this portion of the study are listed in table 4.4.

Differences in the posture between the sexes of the same species reflected very minor differences in the Mann-whitney non-parametric analysis (tables 4.5.1. and 4.5.2). In *Callithrix jacchus*, the males utilized posture A more than the females ($p=0.0601$), while the females used posture B more than the males ($p=0.0601$)(table 4.5.1.). There was no significant difference in the use of posture C in *Callithrix jacchus*. For *Saguinus fuscicollis*, there was no significant difference between the sexes in the medians for the use of any of the postures (table 4.5.2).

When the percent of time each posture used by each species were placed in pie charts the differences were obvious (Figures 4.5.1 and 4.5.2). As in the use of substrates, *Callithrix jacchus* reflects a greater amount of variability in its postures than does *Saguinus fuscicollis*.

Figure 4.4 - Posture B exhibited by *Callithrix jacchus*. There is an adduction of the limbs towards the sagittal plane.

Table 4.4 - Mann-Whitney-Wilcoxon results for percentage of different postures used by each species. P= the probability of a difference between the two medians. W= the sum of the rank sums for both species.

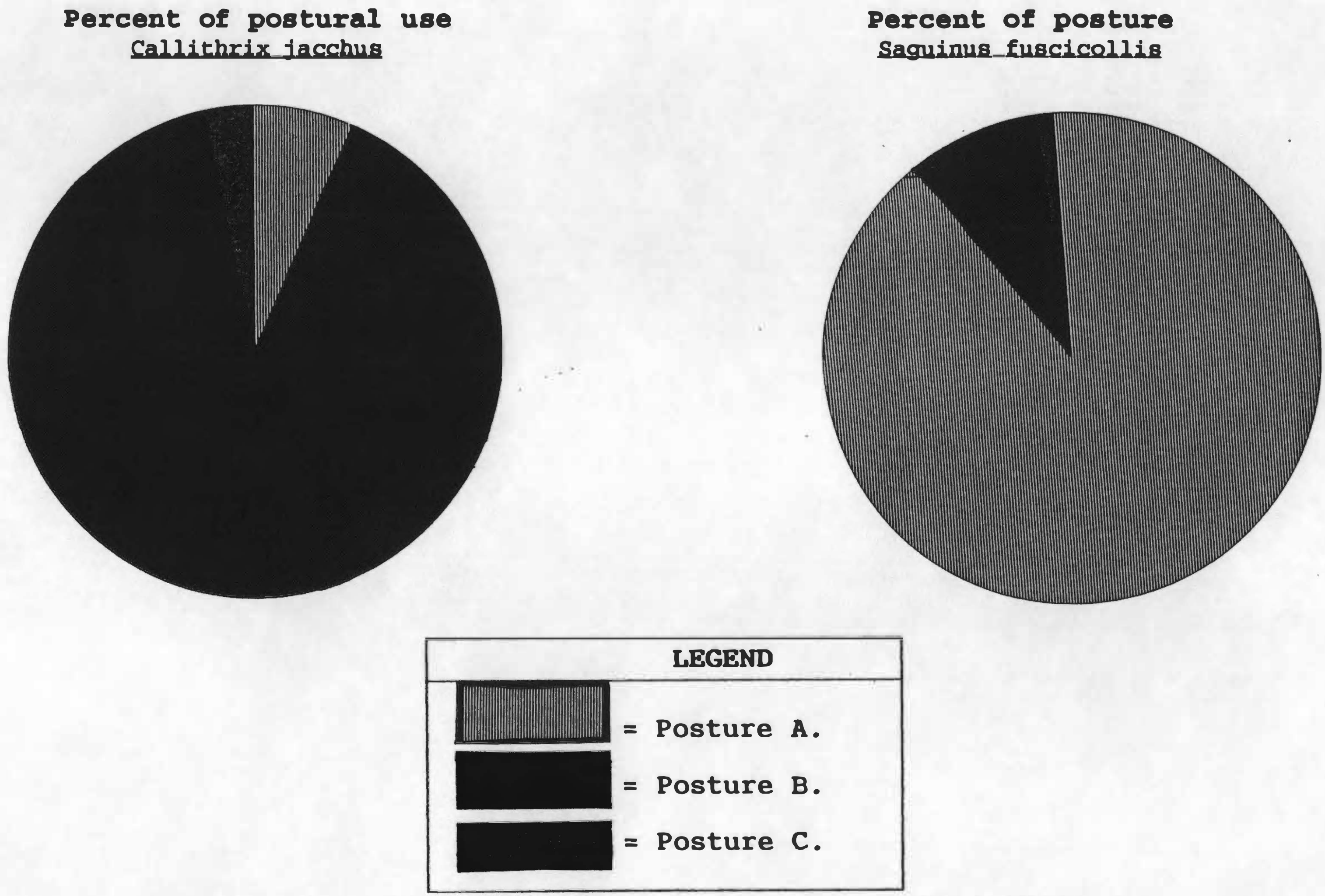
	Callithrix jacchus		*Saguinus fuscicollis*		P-value	W
	# of subjects	Median	# of subjects	Median		
Posture A	10	4.455	8	90.602	.0004	55.0
Posture B	10	90.541	8	7.824	.0004	135
Posture C	10	2.964	8	0.841	.2135	109.5

Table 4.5.1 - Mann-Whitney-Wilcoxon results for percentage of different postures used by each sex in *Callithrix jacchus*. P= the probability of difference between the two medians. W= the sum of the rank sums for both sexes.

	Female		Male			
	# of subjects	Median	# of subjects	Median	P-value	W
Posture A	5	2.99	5	12.50	.0601	37.0
Posture B	5	96.15	5	86.11	.0601	18.0
Posture C	5	0.00	5	3.226	.4034	32.0

Figure 4.5.2 - Mann-Whitney-Wilcoxon results for the percentage of different postures used by each sex in *Saguinus fuscicollis*. P= the probability of a difference between the two medians. W= the sums of the rank sums for both sexes.

	Female		Male			
	# of subjects	Median	# of subjects	Median	P-value	W
Posture A	4	91.55	4	90.60	.8852	17.0
Posture B	4	7.20	4	7.82	.8852	97.0
Posture C	4	0.841	4	1.083	0.665	16.0



Figures 4.5.1 and 4.5.2 - Pie charts of the percent of postural use in *Callithrix jacchus* and *Saguinus fuscicollis.*

The results accumulated from this study will be discussed in regards to factors affecting posture choice and its impact on the time spent using the substrates.

V. DISCUSSION.

This section discusses the results of this study. While there were no significant differences observed in the results of utilization of substrates, there may be factors which affected these results. These factors will be discussed in the following section. The differences in the posture were substantial and these will be discussed following the section on substrate use.

1. Factors affecting utilization of substrates-

While there were no outstanding distinctions between the two callitrichid species regarding the time spent on different substrates in a captive environment, this does not mean that *Saguinus fuscicollis* and *Callithrix jacchus* are similar in their use of substrates in wild populations. Garber (1992) has already suggested that they do not share similar patterns in feeding behavior and that this is reflected in their positional behavior. The results of this study may have been affected by several factors.

One of the first notable factors which may have influenced this study concerns how the subjects were housed.

All of the animals utilized in this study were housed in "single" cages (Carson, pers.com.,1993). The individual cages consist of a wire cage and one horizontal substrate. If the individuals were not as familiar with vertical substrates as they were with the wire and horizontal substrates, this could influence the results. The subjects might be less likely to utilize strange and unfamiliar substrates versus those they might be more comfortable using. The three animals, MH-5086, MJ-5535, and FJ-5626, which spent a greater amount of time on the vertical substrates had a longer adjustment period to the new surroundings.

The adjustment to new surroundings may also have been a factor in the results of this portion of the study. The subjects were placed in the enclosures the afternoon prior to the morning studies; this allowed for approximately a twelve-hour adjustment period. MJ-5535, MH-5086, and FJ-5626 were placed in the cages the Friday afternoon before the Monday morning study. This allowed for approximately sixty hours to adjust to their new surroundings; almost five times as long as the other subjects except for one female *Saguinus fuscicollis*.

Other factors which may have influenced the data include the techniques used by the researcher to accumulate the data. There is a possibility that the amount of time studying these two callitrichid species might not have been substantial enough to accumulate significant data on substrate utilization. Another factor which might have influenced the data is the number of subjects used in this study. Ten *Callithrix jacchus* and eight *Saguinus fuscicollis* individuals were utilized for this study; if more subjects had been analyzed for differences the results might have been significant.

The final factor to be considered is not as strong as the previous ones discussed, however, it may have been a factor in this study. The difference may have been affected by the subjects' environments. In wild populations, there is greater mobility in movement and more versatility in vertical and horizontal substrates than in a captive population.

All of these factors may have influenced the results of this portion of the study. Further studies under similar conditions are required to analyze the utilization of substrates by these two callitrichid species.

2. Posture of callitrichids-

Unlike the utilization of substrates, the posture of callitrichids appears to be influenced by limb morphology, and not behavior. The definite difference between the two species seems to indicate an anatomical factor may influence the posture of *Callithrix jacchus* and *Saguinus fuscicollis*.

The median for posture A was 90.62 % for the saddle-backed tamarin, whereas for the common marmoset the median was only 4.46 %. However, the median for posture B was 90.54 % for *Callithrix jacchus*, while for *Saguinus fuscicollis* the median was 7.82 %. Previous morphometric studies on limb length in callitrichids (Falsetti, 1986) reflected an increased forelimb length in *Saguinus fuscicollis* when compared with *Saguinus oedipus*. Other researchers (Falsetti and Cole, 1992; Garber, 1992; Hershkovitz, 1977) have argued that the saddle-backed tamarin has longer limbs than other callitrichids, including the common marmoset.

The results seem to show a possible effect of increased limb length on postural behavior in *Callithrix jacchus* and *Saguinus fuscicollis*. The saddle-backed tamarins appeared to utilize the posture in which the limbs were held away from the body, while the common marmoset appeared to prefer the posture in which the limbs were held below the body. A small-bodied primate with longer limbs might use a posture which would keep its body close to a substrate for prevention of predation.

The difference in posture may also be correlated to feeding patterns exhibited in wild population studies (Garber, 1992). *Callithrix jacchus* is primarily an exudate feeder, whereas, *Saguinus fuscicollis* has a diet which consists primarily of insect predation. The feeding on gum would be more advantageous if the body and head were held close to the trunk, which may influence the propensity for shorter limbs. Predation on insects would require quick leaps from substrate to substrate; this would be more advantageous with the increased limb length. The longer limbs would serve as shock-absorbers for the leaps from trunk to trunk and would allow for versatility of rapid movement on both small and large substrates.

A detailed analysis of limb length in callitrichids, particularly *Callithrix jacchus* and *Saguinus fuscicollis*, would support or refute this theory on posture and limb length in tamarins and marmosets. If there is a correlation, these studies may be applied to other primate species to see if this trend occurs across the order *Primates*.

VI. CONCLUSIONS

This study has attempted to determine if there was any difference in the utilization of substrates by two callitrichid species, *Callithrix jacchus* and *Saguinus fuscicollis*. In the course of this study, posture was also noted as being significantly different for each species. While the utilization of vertical substrates did not appear to be significantly different for each species, there may have been several factors which affected these results. These include:

A. Familiarity with the enclosure and the length of adjustment time for the subjects.

B. Number of subjects used in the study.

C. Previous enclosures in which the subjects were housed.

The postural data indicates a morphological factor may influence the posture which each species primarily utilized. The longer limbed *Saguinus fuscicollis* appeared to use a posture in which the limbs were held away from the body; while the shorter limbed *Callithrix jacchus* seemed to use a posture in which the limbs were held directly beneath the body. These differences may correlate to feeding patterns observed in wild populations. There would be a greater chance for a primarily exudate-feeder, such as *Callithrix jacchus*, to adopt a posture which would place the head and body closer to a trunk. Whereas in a species which is a primary insect feeder, such as *Saguinus fuscicollis*, versatility in posture and limb length mat aid in sucessful predation on different substrate sizes.

In the case of substrate utilization, further studies on both captive and wild populations would provide more substantial results. Ecological and anatomical studies correlated with the postural data would help to confirm the theories suggested by the analysis of this study.

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