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Allometric Variation of the Postcranial Skeleton in two South American Tamarins *Saguinus oedipus oedipus* and *Saguinus fuscicollis illigeri* (CALLITRICHIDAE, PRIMATES)

Anthony B. Falsetti
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I am submitting herewith a thesis written by Anthony B. Falsetti entitled "Allometric Variation of the Postcranial Skeleton in two South American Tamarins *Saguinus oedipus oedipus* and *Saguinus fuscicollis illigeri* (CALLITRICHIDAE, PRIMATES)." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Fred H. Smith, Major Professor

We have read this thesis and recommend its acceptance:

William M. Bass, Richard L. Jantz, Margaret Wheeler

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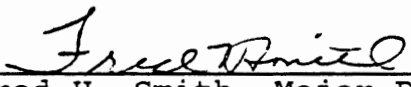
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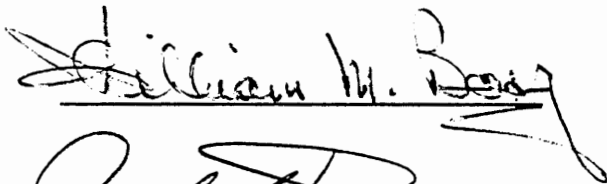
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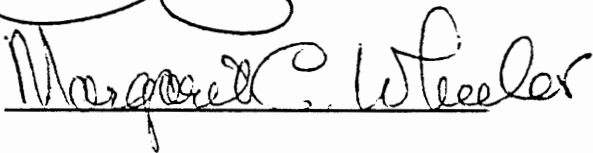


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We have read this thesis
and recommend its acceptance:







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and Dean of The Graduate School

ALLOMETRIC VARIATION OF THE POSTCRANIAL
SKELETON IN TWO SOUTH AMERICAN
TAMARINS SAGUINUS OEDIPUS OEDIPUS
AND SAGUINUS FUSCICOLLIS ILLIGERI
(CALLITRICHIDAE, PRIMATES)

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

Anthony B. Falsetti

June 1986

For Kristin

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ABSTRACT

This research examines several aspects of allometry in the postcranial skeleton of two South American tamarins Saguinus oedipus oedipus and Saguinus fuscicollis illigeri. The statistical method used for analyzing these groups is reduced major axis regression. Bivariate plots are used to qualitatively evaluate group differences, particularly in regard to differing locomotor behavior. The allometric variation in the postcrania of these two species is described. Finally, allometric comparisons between these groups are made.

Heterochronic terminology is used to describe the allometric patterning. The most important result of this study is that geometric similarity was determined to exist between the groups. The comparisons support the contention that Saguinus oedipus oedipus is, in allometric terms, a geometrically "overgrown" Saguinus fuscicollis illigeri. Analysis of the bivariate plots reveal that significant differences in slope values between the species examined may be related to the documented anatomical locomotor variability exhibited by S.o.oedipus and S.f.illigeri.

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CHAPTER I

INTRODUCTION

Tamarins are small, long-tailed, exclusively arboreal, diurnal New World monkeys. They have a tendency to twin, live in small groups comprised of an average 6-7 individuals, have clawlike nails on all the digits except the hallux, and have tritubercular upper molars. Tamarins are also omnivorous, relying heavily on fruit, flowers, insects and exudates. They are essentially quadrupedal and inhabit the upper levels of the canopy in many forested regions of South America.

In the early 1960's, tamarins began to be used extensively in many areas of biomedical research (Benirschke and Richart, 1960; Gengozian, 1969, 1971). Conrad Richter of the Oak Ridge Associated Universities, recognized their usefulness as research animals and began an extensive breeding program both for research and to preserve these endangered species. Tamarins have proved their usefulness in biomedical research in one area in particular, colonic carcinoma (Gengozian, 1969). Tamarins appear to be the only primate, other than humans, that contract this form of cancer spontaneously, which makes them an invaluable model for study.

While tamarins have been utilized in biomedical research, they have rarely been analyzed from an anthropological perspective. Most anthropological studies of tamarin skeletal morphology (Ford, 1980; Glassman, 1982, 1983; Levitch, 1986; Schmidt, 1984) suffer from small sample sizes. This study attempts to remedy that problem by increasing dramatically the sample size compared to them.

This thesis attempts to provide an extensive survey of the tamarin postcranium from the standpoint of allometric variability and will utilize the largest tamarin postcranial series available to date. Postcranial variability will be described for two closely related species Saguinus oedipus oedipus and Saguinus fuscicollis illigeri.

The purpose of this thesis is twofold: (1) to examine the relationship between size and shape and how these factors combine together to reflect the locomotor differences of the species, and (2) assess the effects of different body size has on the postcranial skeleton of closely related species.

Certain assumptions must be made in any form of research. The major assumption in this study is that while almost all of the individuals utilized for this study died prematurely (the major cause of death in the tamarins included in this analysis is pneumonia)

their premature deaths did not significantly alter their skeletal development (Tardiff, 1986).

Since the collection contains both colony and wild born individuals (with the former constituting the majority), it is also necessary to assume that skeletal development does not differ significantly between these two subsets of the total sample. Previous studies (Glassman, 1983; Schmidt, 1984) have generally demonstrated this to be the case, and this research also yields data which support this assessment (see Chapter IV).

CHAPTER II

THE BIOLOGY OF TAMARINS

The following is a brief discussion of various aspects of the distribution, morphology, ecology and behavior of S.fuscicollis illigeri and S.oedipus oedipus. It is intended to provide background on those aspects of tamarins which are pertinent to the research reported in this thesis. Further, more detailed information on specific aspects of the biology and behavior of tamarins may be found in numerous sources (e.g., Albrech, 1982; Ankel-Simons, 1983; Baba et al., 1975; Coimbra-Filho and Mittermeir, 1973, 1977; Cronin and Sarich, 1975, 1978; Dawson, 1976, 1979; Dixson and George, 1982; Epple, 1977; Fleagle and Mittermeir, 1980, Ford, 1980; Garber, 1980, 1984; Gengozian, 1971; Gengozian and Deinhardt, 1978; Glassman, 1982, 1983; Hearn, 1977; HersHKovitz, 1969, 1972, 1975, 1979; Jolly, 1972; Kinzey, 1979; Leutnegger, 1973, 1978; Napier and Napier, 1967; Stallings and Mittermeir, 1983; Soini, 1982; Sussman, 1985; Sussman and Kinzey, 1984 and Terborgh, 1983).

1. Taxonomy

Saguinus fuscicollis and Saguinus oedipus are

members of the South American primate family, Callitrichidae, which is made up of four genera: Callithrix, common marmosets; Cebuella, pygmy marmosets; Saguinus, tamarins; and Leontopithecus, the lion tamarins. Hershkovitz, (1977) recognizes thirteen subspecies of Saguinus fuscicollis and two subspecies of Saguinus oedipus. Subspecies designation reflects various minute intraspecies variation in morphology ecology and/ or behavior (Ankel-Simons, 1983; Glassman, 1982).

2. Geographic Distribution

Saguinus fuscicollis is found in the Upper Amazonian region from the west bank of the Rio Maderia south of the Rio Amazonas in Brazil, and the south bank of the Japura'-Rio Cagueta-Caguan north of the Amazonas in Brazil and Columbia, Equador, Peru and Bolivia (Hershkovitz, 1977). The subspecies used in this study, Saguinus fuscicollis illigeri, is found in the western region of the area (Sussman and Kinzey, 1984).; specifically, in Loreto, eastern Peru (Figure 1.). These animals range between the lower Rios Huallago and Ucayali, from the south bank of the Maranon south to the Rio Caxiabatay and, possibly, to the Pisqui (Hershkovitz, 1977).

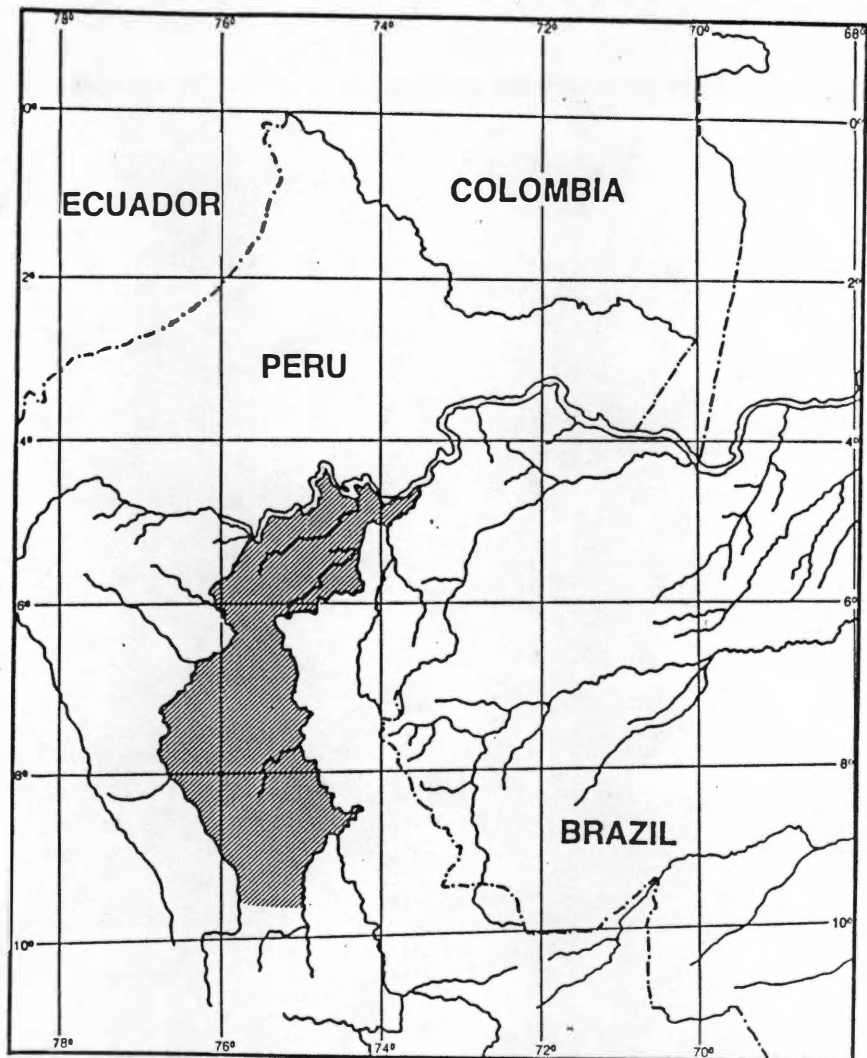


Figure 1. South American geographical distribution of *Saguinus fuscicollis illigeri*.

Saguinus oedipus oedipus is found in the tropical forested area extending from southern Costa Rica to northern Colombia between the Rio Arato to the west and the departments of Atlantico, Bolivar, Cordoba, northwestern Antioquia, and Choco to the east (Hershkovitz, 1977; Sussman and Kinzey, 1984). Saguinus oedipus oedipus distribution is illustrated by Figure 2.

3. Morphology

The Callitrichidae are small, long-tailed New World monkeys that possess a number of morphological characteristics rare among primates. The most striking characteristic of S.fuscicollis and S.oedipus, as well as the Callitrichidae in general is their small body size compared to other primates. Saguinus body size is often approximated to that of a squirrel. The smallest callitrichid, Cebuella, is among the most diminutive of all primates, with a size overlapping or slightly greater than Microcebus, the mouse lemurs Tarsius, and the smallest species of Galago, Galago demidovii (Clutton-Brock and Harvey, 1978, 1979, 1983; Napier and Napier, 1967).

Saguinus species body weights range from 250 to 550gm (Sussman and Kinzey, 1984) and have a long tail compared to body length. In general, S.oedipus tends to be slightly larger than S.fuscicollis in head and



Figure 2. South American geographical distribution of *Saguinus oedipus oedipus*.

body length and in tail length, however interspecies, comparison produces an extensive overlap. S.fuscicollis has a body length (head included) in the range of 175-220mm and a tail length of 250-383mm; S.oedipus has a body length in the range of 200-287mm and a tail length of 302-423mm (Hershkovitz, 1977). The tails are covered with fine "silky" hair, and exhibit a number of distinct color patterns distributed among the species and various subspecies. The tails are not prehensile, and do not seem to serve a stabilizing or grasping function (Hershkovitz, 1977). The percent of tail length to body length (including the head) is 145.0% for S.fuscicollis and 155.3% for S.oedipus (Hershkovitz, 1977:945).

Tamarins exhibit diversified color patterns, and the various species and subspecies possess a variety of diagnostic crests, tufts, and manes (Glassman, 1982). The face of the adult S.oedipus is black and the temples and sides of the head are almost bare, generally having only a thin covering of short hair (Hershkovitz, 1977). A diagnostic feature of S.oedipus oedipus is the presence of two bands of grayish or whitish hair on the face. The supraorbital band extends from the outer corner of the eye to the gonial angle of the jaw on the periphery of the face. The second band begins at the

sides of the nasal bridge (above the projecting muzzle), and stretches downward surrounding the mouth, and is continuous in forming the breast (Herskovitz, 1977).

The more common name for S.oedipus oedipus is the cotton-top tamarin. This derived from a diagnostic crest of hair beginning in the midfrontal region. It often begins as a peak, and continues as a mane of long whitish hair, extending posteriorly behind the ears and down the nape of the neck. The pelage of S.oedipus is often divided into two distinct shades, white and black. The long hair of the chest, abdomen, forelimbs and posterior regions of the hindlimbs is white, which darkens slightly to the pale grey of the feet. The back, shoulders, and the anterior areas of the hindlimbs are dark, ranging from black to reddish-brown, and are covered by hair of similar length to that of the chest.

The adult face of S.fuscicollis is covered with hair (Glassman, 1982; Herskovitz, 1977). This differs markedly from S.oedipus. One of the most diagnostic features of S.fuscicollis is the short whitish-grey hair which surrounds the mouth region. Black or dark brown hair is found on the animals crown and forehead and continues down to the nape of the neck. On the backs of all the subspecies of S.fuscicollis is a well defined patch of hair. This patch of hair is mottled grey and

brown, giving a marbled appearance from which the common name for this species, the saddle-back tamarin, is derived. The subspecies used in this study possess dark brown to reddish-brown, or chesnut to reddish hair, on the shoulders, rump and limbs (Glassman, 1982; HersHKovitz, 1977; Schmidt, 1984).

The adult dental pattern for S.oedipus and S.fuscicollis is similar and both have a dental formula of 2-1-3-2 and a deciduous pattern of 2-1-3. Saguinus incisors are spatulate, expanded and shorter than the canine teeth (Sussman and Kinzey, 1984; Swindler, 1976). All incisors exhibit a well developed lingual cingulum, and the upper central incisors tend to be much larger than the lateral incisors. The lower incisors are subequal in size and approximately the same height, and a small enamel phalange is present on the distal margin of I2. The canines are long, projecting, sharp-pointed, and somewhat triangular in cross-section (Ankel-Simons, 1983; Glassman, 1982; Swindler, 1976). The upper canine is separated from I2 by a diastema but is contact with P2. The canine is elongated beyond the occlusal plane and exhibits a complete lingual cingulum (Swindler, 1976). A distinct mesio-lingual groove is also present in both the upper and lower canines.

The upper premolars are biscuspid and the protocone is dominant. The lower premolars are caniniform, with a larger protoconid and a well formed lingual cingulum (Ankel-Simons, 1983; Swindler, 1976). The upper molars are three cusped (tritubercular) and lack a hypocone. The M2 is much smaller than M2 (Swindler, 1976). The lower molars have four cusps, no hypoconulid, and the mesial two cusps are connected by a protocristid. There is no transverse nexus between the distal cusps (Swindler, 1976). Glassman (1982) reports that P2 is more molarized in S.oedipus than in S.fuscicollis.

Tamarins also possess claws on all digits except the hallux, which exhibits a flattened nail. This condition is unique to the callitrichids, and has sparked much debate. It has been suggested to be either a "primitive" characteristic, or an adaptive mechanism enabling them to more efficiently exploit their unique ecological niche (see Cartmill, 1974; Ford, 1980; Garber, 1979; Rosenberger, 1977; Sussman and Kinzey, 1984 and Thorndike, 1968 for more in depth discussions of this topic).

4. Ecology/Behavior

Callitrichids, in general, are quite diverse in their selection of habitats. Interspecies variation has

been noted (Castro and Soini, 1977; Glassman, 1982; Moynihan, 1970 and Sussman and Kinzey, 1984), but it is generally considered to be seasonally dictated. In captivity, however, where season and diet is controlled, it has been noted that S.fuscicollis primarily inhabits the lower branches of their enclosures, while S.oedipus spends a greater amount of time in the higher areas (Glassman, 1982). This observation is also in agreement with the data from the field (Izawa, 1976; Moynihan, 1970; Neyman, 1977; Pook and Pook, 1982; Sussman and Kinzey, 1984 and Terborgh, 1983).

Tamarins are most often considered to be omnivorous and exploit three primary food sources: insects; fruits, flowers, and nectar; and plant exudates (Sussman and Kinzey, 1984). Kay (1975) and Moynihan (1970) both make reference to the proportionality of body size to insect intake in the diet of primates. Smaller primates are in an advantageous position to obtain protein from insects, where larger forms are restricted to folivorous items to fulfill their dietary needs (Sussman and Kinzey, 1984). The small body size of Saguinus enables it to exploit the terminal ends of branches almost exclusively without competition from other primates. Both marmosets and tamarins eat fruit; however, reports from the field seem

to indicate that tamarins tend to eat more fruit than marmosets (Sussman and Kinzey, 1984).

Tamarins and marmosets have both been observed feeding on tree exudates (Castro and Soini, 1977; Garber, 1979; Izawa, 1976, 1978; Neyman, 1977 and Terborgh, 1983). Garber (1979, 1980, 1984) reports that tree exudates account for approximately 14% of the tamarin diet. The use of tree exudates as a means of balancing the tamarin diet between fruits and insects has been suggested by Garber (1984). In reference to the gum-feeding behavior of tamarins, Sussman and Kinzey (1984) point out that tamarins do not chew wood or dig into the branches or trunks of trees, but rather they exploit exudates that flow as the result of some sort of natural or insect inflicted injury to the host. This is in contrast to the specialized exudate removal behavior of marmosets, which possess a modified dental morphology which enhances this activity (Kinzey et al., 1975; Moynihan, 1970, 1976; Ramirez et al., 1977 and Soini, 1982). For the marmoset, exudates are the primary food resource. Soini (1982) reports that exudate feeding is also the prominent daily activity in Cebuella. This has also been reported by Ramirez et al. (1977) and Terborgh (1983).

Both S.fuscicollis and S.oedipus live in small groups. These groups range in size from 3-19 individuals, however, the average group is comprised of 6-7 animals (Hearn, 1977; Neyman, 1977; Sussman and Kinzey, 1984). S.oedipus oedipus tends to structure its groups around the small nuclear family comprised of one adult male and female and one to four young (Hamptom et al., 1966; Hershkovitz, 1977), but polyandrous mating has been observed in this subspecies (Hamptom et al., 1966) as well as in Saguinus in general (Epple, 1975; Soini, 1982; Sussman, 1985; Sussman and Kinzey, 1984).

Sussman (1985) reports that in S.fuscicollis only one female gives birth, males help with carrying and feeding the young, and that simple monogamy is rare. However, mating occurs only in one male-female pair. It is interesting to note that in S.fuscicollis groups, only one female is reproductively active (Sussman, 1985). The other females in the group, including the daughters of the pregnant female do not ovulate. The males help in rearing and feeding the young which presumably maximizes infant survival. It has also been recently reported (Sussman and Kinzey, 1984), that all young tamarins help in the feeding and the carrying of the young. In tamarins, dizygotic twinning is the rule rather than the exception (Benirschke and Layton, 1969;

Hershkovitz, 1977; Leutnegger, 1973; Moynihan, 1970; Schultz, 1948; Sussman, 1985 and Terborgh, 1983).

Saguinus, like all members of the primate family Callithricidae, are arboreal and diurnal (Epple, 1975). They predominantly inhabit the forest canopy, and have been observed ranging from 60-75 feet above the forest floor (Moynihan, 1970). Hill (1957) states that Saguinus species are the most perfectly adapted of all the primates for their arboreal existence. Tamarins are almost exclusively quadrupedal, and their locomotor activity is often compared to that of the squirrel. However, this comparison is oversimplified. During disputes or to better visualize a distant animal, tamarins occasionally stand up on their hindlimbs. They will run on the ground and on branches in a similar manner to squirrels; however, tamarins tend to leap from branch to branch far more frequently than the squirrel, and their leaps seem to be somewhat longer on the average (Garber, 1980; Monihan, 1970). Hershkovitz (1977:45) reports the following: "...they are essentially quadrupedal branch runners and springers with hindlimbs averaging approximately 25% longer than forelimbs. Saguinus utilize their long, sharp claws on the forelimbs to cling vertically to branches, while using the longer, more powerful hindlimbs to generate the propulsion of a leap."

Thorington (1968) reports tree to tree leaps of up to 25 feet in length for S.midas. Neyman (1978) and Castro and Soini (1978) also report that S.fuscicollis and S.oedipus move through the trees using mainly a quadrupedal gait, and at times with occasional horizontal and diagonal leaps from tree to tree. Napier and Napier (1967) classify Saguinus locomotor behavior as quadrupedal with springing and jumping great distances the most prominent mode of transportation. While being well documented for the genus, little work has been done with intraspecific data.

However, Glassman (1983) reports that locomotor behavioral differences between the two congeneric species, S.oedipus oedipus and S.fuscicollis illigeri, have been noted in captive animals at the ORAU marmoset breeding colony. Glassman (1983:292) states:

... data were obtained from observations of captive animals. Richter and Davis (personal communication) suggest that observable differences can be identified between S.fuscicollis illigeri and S.oedipus oedipus in both the utilization of cage space and locomotor activity. S.fuscicollis sits and walks on the cage floor much more frequently than does S.oedipus which rarely comes down to this level. In terms of locomotion, they suggest that both progress similarly when walking, yet in terms of rapid movement and leaping, S.oedipus is undoubtedly a more powerful and longer leaper than S.fuscicollis.

Glassman (1983) further provides a rotated principal components analysis which bears out the intraspecies

differences, particularly in limb proportions and in the position of muscle attachment areas (specifically in the olecranon process of the ulna). Furthermore, the interspecies anatomical differences are all related to areas which are functionally consistent with a greater morphological adaptation in S.oedipus oedipus for the generation of propulsive forces than in S.fuscicollis illigeri. Therefore, differences in locomotor behavior may be reflected in skeletal morphology.

CHAPTER III

THE STUDY OF ALLOMETRY

The study of allometry, defined by Gould (1966:587) as "the study of size and its consequences," has received a great deal of attention in the biological sciences. Since their introduction by Sir Julian Huxley in 1932, allometric studies have been utilized in the areas of biology, paleontology, genetics and most recently physical anthropology (e.g., Aiello, 1981; Albrech et al., 1979; Corruccini, 1975, 1983; Cheverud, 1982; Gould, 1966, 1971; Jolicoeur, 1963a, 1963b, 1963c, 1984; McKinney, 1984; McNamara, 1986; Pirie, 1978; Shea, 1981, 1983, 1984, 1985 and Jantz and Owsley, 1984). Recent refinements and revisions in theory and methodological applications, specifically by Cock (1966), Cheverud (1982), Gould (1966), Jolicoeur (1963a, 1984), Shea (1985) and Smith (1980), have increased the application of allometry to questions regarding growth, size and their evolutionary consequences.

Allometry may be defined as the quantitative and statistical exploration of the relationships of size, shape and adaptation between anatomically defined units which reflect aspects of growth and development. Interpretation of the quantitative evidence enables

researchers to gain insight into the complexity of the relationship between development, physiology, behavior and ecology (Lauer, 1975; Larson, 1981, 1984; Case, 1978).

1. Ontogenetic Allometry

Ontogenetic studies, or those which examine growth, generally attempt to isolate patterns of relative growth within (intraspecific) and between (interspecific) species. In ontogenetic allometry analyses, the individuals being compared are growth stages in a single species (cross-sectional studies). Intraspecific studies compare size-related changes between individuals of the same species. Additionally, interspecific studies attempt to compare growth trajectories between individuals of different species. Finally, within each of these allometric analyses there are a number of peculiarities inherent in the nature and biological interrelationships of the measures being examined (Fleagle, 1985).

Huxley's (1932) formulation of the allometry equation,

$$y = bx^k$$

where k is the ontogenetic allometry coefficient and represents the growth ratio between two anatomical

units, X and Y , and b is a constant, forms the basis of most allometric studies. Huxley's emphasis was to "demonstrate the existence of certain broad empirical laws of relative growth" (Huxley, 1932:2). His analysis of relative growth was concerned with the explanation of growth gradients from a cross-sectional population. This differs from what has come to be called size allometry, which focuses on allometric changes in a static adult series (Shea, 1985).

2. Static Allometry

Studies of static, or size allometry describe the proportional variation in the adult organisms of a single species. Static allometric studies also examine the proportional variation within a smaller subdivision, such as a subspecies or a population. As in ontogenetic allometric studies, static allometric formulae describe the proportional variation within a sample. Therefore, the static allometry coefficient represents relative growth when it is equal to the average ontogenetic allometry coefficient (Cheverud, 1982). The use of static data for allometric analysis is a common method, particularly for questions concerning evolution and its consequences (German and Jungers, 1980; Jungers, 1984; Jungers and German, 1981).

3. Evolutionary Allometry

Evolutionary allometric studies are becoming very popular in anthropology and biology. Evolutionary allometry involves comparisons of different taxa or different populations of the same species. Evolutionary allometry usually involves the study of size and shape changes through time in a phyletic sequence. Studying allometric relationships through time may be of great importance in understanding selectively induced morphological changes (Gould, 1966). Evolutionary allometric comparison can either be made between the extant ends of phylogentic branches or within lineages. Gould's (1966) view of evolutionary allometry identifies size change as an important theme in evolution, and allometric techniques may be used to examine such diverse topics as increases in metabolic efficiency with larger body size and brain/body evolution in hominids (Hemmer, 1969; Jerison, 1973; Pilbeam and Gould, 1974).

Pilbeam and Gould (1974) present a brain/body size evolutionary allometric study utilizing hominids and pongids. Their results present an increase in ectocranial volume relative to body weight in Homo as compared to australopithecines and pongids. In Homo brain size is positively allometric. Similar slope values are found between australopiths and pongids.

In their comparison of the robust and gracile australopithecines, Pilbeam and Gould (1974) argue for a geometric size increase in the dentition, relating this phenomenon to masticatory functions.

One of the problems encountered by Pilbeam and Gould (1974) was their lack of juvenile specimens, thereby making their allometric scaling differences somewhat presumptuous. Gould (1977) recognized this problem and began a meticulous re-examination of the roles of neotony and acceleration in terms of fields of growth. Gould's (1977) emphasis is on refining and exploring the ramifications and applications of the concepts of hypermorphosis, neotony and progenesis, all which fall into the category of heterochrony.

4. Heterochrony

Heterochrony is "...the phenomenon of changes through time in appearance or rate of development of ancestral characters" (McNamara, 1986:4). Heterochrony describes how descendent species differ from their ancestors in the onset, rate and duration of growth (McKinney, 1984; McNamara, 1986). The postcranial data employed in this analysis do not in the strictest sense, adhere to the definition of heterochrony for two basic reasons. The first reason is because the are measures

of adult postcrania thus they represent a static, rather than an ontogenetic series. An ontogenetic, or growth, series is usually the proper data source, however it must be remembered that adult postcrania represents the endpoint of the various growth processes, and should reflect those processes in the measures taken in this study. Secondly, the phylogenetic relationship between Saguinus oedipus oedipus and Saguinus fuscicollis illigeri is not an ancestor-descendent relationship. Rather, they are closely-related, extant tamarin species.

The concept of "geometric similarity" (Gould, 1971) has been used to describe allometric relationships which are not technically heterochronic. Geometric similarity describes the interspecific relationship of slopes between closely-related species via transposition. Therefore, the two species are geometrically similar with regard to shape and size for the variables being examined. The transposition of the regression lines (Pre or Post-displacement) is interpreted as the representation of the larger of the two species retaining the functional equivalence of the measure being examined. Functional equivalence describes the relationship of two variables which, while one is larger, share the same function. In effect, the increase in size, or shape,

does not change the function of the morphological structure. While a true heterochronic analysis is not assumed, the definitions of heterochrony will be used in a manner which reflects the geometric relationship between the variables for the two species.

An excellent review of heterochronic terminology is provided by McNamara (1986), Gould (1977), Albrecht et al. (1979), and Shea (1983). The following is a brief review of the various terms used to describe the different heterochronic processes.

The term Paedomorphosis is used to describe situations in which the adults of a descendent species resemble the subadults of the ancestral species in shape, but not necessarily size. There are three forms of paedomorphosis; progenesis, neoteny and post-displacement. In Progenesis the descendent follows the same growth gradient as the ancestor, but is dramatized by a pattern of "precocious sexual maturation" (McNamara, 1986:6). Thus Neoteny is a state in which the members of the descendent species resemble juveniles of the ancestral species in form. However, the adults of the descendent species are larger in size. Neoteny represents a condition of a reduced morphological rate of development. Post-displacement reflects a delayed onset of growth in the descendent species.

The descendent species thus grows for a shorter duration of time.

The cases of heterochrony in which the descendent growth trajectory extends "beyond" the ancestral adult stage, are described as peramorphosis (McNamara, 1986). Peramorphosis is also divided into three types; hypermorphosis, acceleration and pre-displacement. The term Hypermorphosis is used to describe a situation in which the descendent species develops along the ancestral species growth trajectory for a longer period of time. In Acceleration, the descendent species grows at a faster rate than the ancestor. Acceleration represents an increased rate of morphological development, rather an advancement in size (McNamara, 1986). The exact opposite of acceleration, Pre-displacement, results in a descendent which is an overgrown form of the ancestor, but equal in size (McNamara, 1986). Rather, in simpler terms, pre-displacement, reflects an earlier onset of growth.

While these concepts are more applicable to comparisons of ontogenetic data, they can be quite useful to describe static allometric relationships. In this analysis there are no true ancestors and descendents, but heterochronic terminology will be used to describe size-correlated variability, in shape between the species. Saguinus fuscicollis illigeri, for

the purpose of this study, will be considered the ancestor, and Saguinus oedipus oedipus, the larger species, is considered the descendent. Figure 3. schematically illustrates the effects of heterochrony. If, for example, the regression lines for Saguinus oedipus oedipus and Saguinus fuscicollis illigeri are identical, then a case may be made for hypermorphosis. The variability in S.o.oedipus would be considered an extension of the variability exhibited by S.f.illigeri, and the resulting interpretation would be that S.o.oedipus is simply an "overgrown", or geometrically "blown-up" version of S.f.illigeri.

In pre-displacement, the slopes for the two groups would be identical and negatively allometric. In this case, the intercept for S.o.oedipus would be greater. Such a shift in intercept is called a transposition (Gould, 1971) and is necessary to preserve the function of the morphological structure under examination. In post-displacement the regression slopes are parallel and the intercepts of the ancestral species is larger. The shift in the intercept of the larger species (S.o.oedipus) is due to the steepness of the slopes, and the intercept is transposed below that of the smaller species (S.f.illigeri). Therefore, the transposition acts in a similar fashion as in pre- displacement.

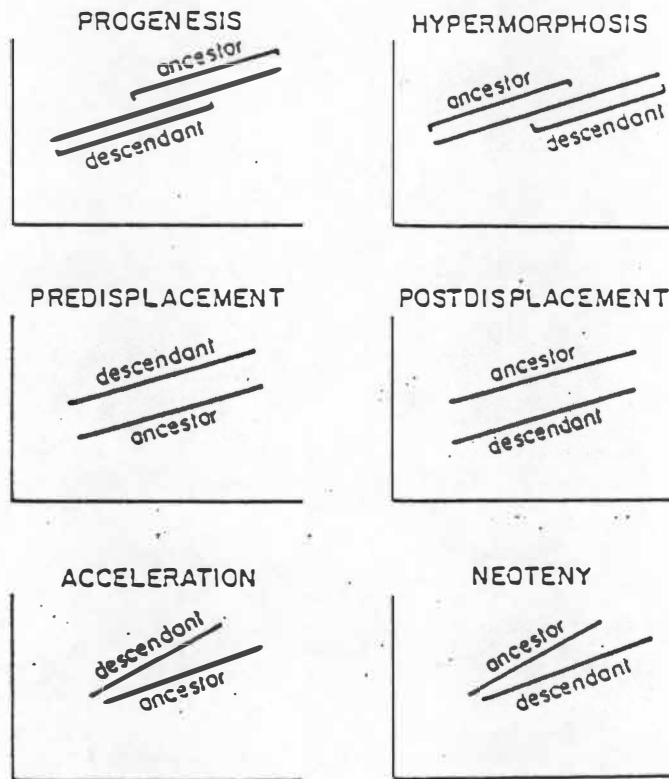


Figure 3. Schematic illustration of Heterochronic effects (In press). Courteously provided by Dr. M. McKinney.

Acceleration and neoteny are easy terms to abuse, particularly in the case of static data. In this study, they are being used to describe the static scaling phenomenon of the larger species (S.o.oedipus) relative to that observed in the smaller species (S.f.illigeri). In the case where the regression line of Saguinus oedipus oedipus is more positively allometric than that of Saguinus fuscicollis illigeri, a relationship of acceleration may exist. Where the regression line for S.o.oedipus is more negatively allometric the term neoteny will be utilized.

5. Statistical Methodology

The most popular statistical technique in the examination of size and shape is the linear regression. Huxley (1932) developed and examined the statistical inferences from "constant differential growth rates" which he summarized in the following formula:

$$y = bx^k$$

In the formula, k is a constant and represents the ratio of growth rates of the variables Y and X . Also, b is a constant (Huxley, 1932). The formula is log-transformed, in accordance with the "power" Huxley's (1932) equation requires, and is presented below:

$$\log y = k(\log x) + \log b$$

This transformation enables the investigator to make a clear examination of the relationship between the variables.

There are various techniques for fitting a regression line to log-transformed data. The two most popular techniques, or models, are least-squares linear regression and reduced major axis analysis (see Sokal and Rohlf, 1981; Wolpoff, 1985).

The first method for producing a linear equation, the least-squares linear regression techniques, "provides a predictive generalization about the linear dependence of the dependent variable on the independent one" (Wolpoff, 1985). In its simplest form, this method is used to predict a dependent variable from an independent variable. The method of least-squares fits a regression for a plot of points so that the residual error, rather than the summed differences between the expected and observed values for the dependent variable is equal to zero. It must be noted that least-squares regression analysis assumes that the independent (X) variable has no error of measure, and that any error that exists in the sample lies on the Y axis or dependent variable.

Sokal and Rohlf (1981:412) state that the most productive use of least-squares regression analysis is in cases, "...where dependence and independence may be

justifiably assigned, and where there is no error in the independent variable."

The second method is the reduced major axis (RMA) technique. According to Pilbeam and Gould (1974) reduced major axis regression should be used in allometric research, particularly when structural relationships are being examined. This method does not assume an independent-dependent relationship between the variables under examination. Reduced major axis techniques do acknowledge that, in biological data, there will be few, if any, instances in which one or more of the variables may be considered error-free (Sokal and Rohlf, 1981). This method enables the researcher to examine a linear relationship without the arbitrary assignments of dependence and freedom from error. The reduced major axis technique is best used for examining the functional relationships between morphological variables.

Transformation of the allometry equation,

$$y = bx^k$$

into logarithmic form produces;

$$\log y = k(\log x) + \log b$$

The slope of a reduced major axis regression line (k) is derived by dividing the standard deviation of the Y-axis

variable by the standard deviation of the X-axis variable:

$$k = \frac{sy}{sx}$$

The intercept (b) of the RMA regression line is obtained by the following equation:

$$b = \bar{y} - k\bar{x}$$

where \bar{y} is the mean of the log-transformed Y-axis variable, \bar{x} is the mean of the log-transformed X-axis variable, and k is the slope for the RMA regression line.

The slopes of the reduced major axis regressions are generally higher than those produced by the same variables by least-squares regression. The RMA slope is obtained from least-squares slope output by the following equation:

$$k_{rma} = k_{ls}/(r_{xy})$$

where k_{ls} is the least-squares slope and r_{xy} is the correlation coefficient for the X and Y variables (Pilbeam and Gould, 1974; Sokal and Rohlf, 1981). Testing for slope differences is important, because it enables the researcher to address questions concerning transpositions quantitatively.

Sokal and Rohlf (1981) present a method for testing slope differences in reduced major axis analysis.

The Z-statistic is calculated as follows:

$$Z = \frac{k_1 - k_2}{(S_1^2 + S_2^2)^{1/2}}$$

where k_1 and k_2 are the reduced major axis slopes under comparison and S_1 and S_2 are the standard errors for the regressions. The standard errors for the groups being compared is calculated by the following formula:

$$S_0 = \frac{S_{2y}}{S_{2x}} \sqrt{\frac{1 - r^2}{N}}$$

where S_{2y} and S_{2x} are the variances for X and Y, r^2 is the squared Pearson's correlation coefficient (r_{xy}) and N is the sample size (Sokal and Rohlf, 1985). One of the drawbacks in the application of the RMA method is the difficulty in calculating slope and intercept values. Most obvious is the difficulty in comparing the slopes and intercepts. In least-squares regression packages, such as PROC GLM (SAS, Inc. 1982), analysis of variance is straight forward and accurate. Conversely, in reduced major axis analysis, the calculations are not as easily derived, because computer programs are not yet widely available. Thus calculations for the RMA regressions, for now, must be made by hand.

The choice of least-squares or reduced major axis regressions depends on the questions asked by the researcher. If the hypotheses reflects aspects of functional morphology, then reduced major axis

techniques should be preferred (Gould, 1966, 1975, 1978). Since the data in this study are reviewed in the context of possible functional differences in post-cranial morphology between the two species examined, reduced major axis regression is the more appropriate technique and will be utilized in the analyses that follow.

CHAPTER IV

MATERIALS AND METHODS

The postcranial skeletal data collected for evaluating and describing variation were obtained from the Oak Ridge Associated Universities (ORAU) Saguinus collection currently housed at the University of Tennessee. ORAU has been involved in breeding marmosets and tamarins since 1961 for studies in radiation biology (Gengozian, 1969:351-355; Gengozian 1971; ORAU, 1982:7). Studies generated by ORAU, and others, include aspects of behavior, genetics and anatomy (Gengozian and Deinhardt, 1978).

The successful breeding program and continued importation of animals has resulted in the present colony size of approximately 400 individuals. The colony houses three species: (1) Saguinus fuscicollis illigeri, the saddle-back tamarin, (2) Saguinus oedipus oedipus, the cotton-top tamarin, and (3) Callithrix jacchus, the common marmoset (Tardiff, 1986). Gengozian (1969) presents a detailed description of the ORAU colony, which includes laboratory care of the animals, their caging, and colony environments, diet, and potential for biological research.

In 1978, the Department of Anthropology, the University of Tennessee, Knoxville, Tennessee, was selected as the repository of the well documented collection of autopsied animals.

Since 1978, approximately 1,300 marmosets and tamarins have been processed. A summary of the collection size and distribution is presented by species in Table 1.

The maceration process has been extensively documented elsewhere (Glassman, 1983; Glassman and Webb, 1984; Schimdt, 1984), however, a brief description will be provided. Animals to be macerated were first x-rayed, a scalp fur sample collected, and the dermal surfaces of the fore- and hindlimbs removed and "prepared" in a formaline solution (Glassman and Webb, 1984). The maceration process began by first skinning the animal and then fleshing the remaining tissue from the skeleton. Each animal was then disarticulated at the neck, shoulder, pelvic, and two caudal joints to facilitate their fit into the jars provided for maceration (Glassman, 1982; Schmidt, 1984). The jars were filled with water, and allowed to sit undisturbed for approximately two months. After two months, the material was filtered through a fine mesh screen, the skeleton was dried overnight, then numbered and placed into individual specimen boxes which were then labeled and catalogued.

The sample utilized in this study was limited to specimens from which complete data sets were obtainable. Only adult animals exhibiting no skeletal pathology were included.

Table 1. ORAU Marmoset and Tamarin Cadaver Collection by species.

SPECIES	SPECIES TOTAL
<u>Callimico geoldii</u>	30
<u>Callithrix jacchus jacchus</u>	197
<u>Cebuella pygmaea</u>	5
<u>Saguinus fuscicollis illigeri</u>	1,058
<u>Saguinus fuscicollis lagonotus</u>	151
<u>Saguinus fuscicollis leucogenys</u>	48
<u>Saguinus fuscicollis nigrifrons</u>	154
<u>Saguinus mystax</u>	52
<u>Saguinus nigricollis</u>	65
<u>Saguinus oedipus oedipus</u>	643
Hybrids	228
Unknown	670
Collection Total	3,301

The criteria for determining adult versus juvenile animals included full eruption of the dentition and closure of all the long bone epiphyses. The sample was composed of 37 male and 27 female Saguinus oedipus oedipus and 32 male and 34 female Saguinus fuscicollis illigeri for a total of 130 individuals.

Sample sizes, means, standard deviations, variances, minimum and maximum values and the coefficients of variation by species and sex for both the raw and log-transformed data are given in Tables A1 through A8, Appendix A, respectively. All values were calculated by the MEANS procedure of SAS (SAS Institute, Inc. 1979). Covariance matrices, by species, are provided in Tables B1 and B2, Appendix B, respectively. Similarly all values were calculated by the PROC PRINCOMP procedure of SAS (SAS Institute, Inc. 1979).

Sexes were pooled for each species for the bivariate procedures. The justification for the pooling of the sexes was that the Students' T-test indicated that the sexes were not significantly different. This agrees with the sexual dimorphic data provided by Hershkovitz (1977:674,783; Schmidt, 1984). Table 2. and Table 3. summarize the findings of these T-tests. By pooling the sexes, sample sizes were maximized, and all subsequent analyses were performed with sexes pooled for each species.

Table 2. Results of Saguinus fuscicollis illigeri
Students' T-tests for Sexual Dimorphism.

VAR1	SEX	N	MEAN	STD	T	DF	P
HML	M	32	47.269	1.455	-0.6276	64	0.5325
	F	34	47.519	1.754			
BUE	M	32	7.079	0.365	-0.3467	53	0.1837
	F	34	7.183	0.244			
RML	M	32	42.435	1.587	0.6638	64	0.5092
	F	34	42.176	1.586			
UML	M	32	50.288	1.559	-0.0419	64	0.9667
	F	34	50.306	1.859			
FML	M	32	58.995	2.153	0.6321	64	0.5295
	F	34	58.646	2.316			
FTL	M	32	59.064	2.042	0.8725	64	0.3862
	F	34	58.587	2.372			
TML	M	32	60.920	2.248	1.2390	64	0.2216
	F	34	60.189	2.543			
BPE	M	32	8.235	0.211	0.6346	58	0.5282
	F	34	8.194	0.307			
BDE	M	32	5.338	0.260	1.0897	64	0.2799
	F	34	5.278	0.184			
BML	M	32	57.803	2.143	1.1566	64	0.2517
	F	34	57.159	2.367			
MDS	M	32	3.258	0.207	-0.9595	64	0.3409
	F	34	3.310	0.231			
MDM	M	32	3.275	0.190	0.1118	64	0.9113
	F	34	3.269	0.193			
MDH	M	32	5.948	0.236	0.1459	64	0.8844
	F	34	5.939	0.231			
EBR	M	32	8.705	0.350	0.1690	64	0.8667
	F	34	8.690	0.385			
RDH	M	32	3.829	0.151	-0.7483	64	0.4585
	F	34	3.859	0.169			
BOP	M	32	3.271	0.168	1.1769	64	0.2436
	F	34	3.213	0.224			
MBO	M	32	2.263	0.190	-0.3121	64	0.7560
	F	34	2.281	0.264			
WOP	M	32	4.309	0.222	-2.8450	64	0.0060
	F	34	4.454	0.193			
ORL	M	32	4.253	0.218	1.0915	64	0.2791
	F	34	4.188	0.261			
OCL	M	32	4.128	0.186	0.5126	64	0.6100
	F	34	4.100	0.249			
APD	M	32	3.772	0.171	-0.0906	64	0.9281
	F	34	3.777	0.233			
MLD	M	32	3.609	0.289	0.1354	64	0.8927
	F	34	3.599	0.289			

Table 2. (Continued).

VAR	SEX	N	MEAN	STD	T	DF	P
APS	M	32	3.458	0.152	-1.8929	55	0.0636
	F	34	3.553	0.249			
MLS	M	32	3.897	0.239	-1.2242	59	0.2251
	F	34	3.985	0.342			
VHD	M	32	5.128	0.190	-0.0506	64	0.9598
	F	34	5.130	0.163			
HHD	M	32	5.164	0.206	0.0773	64	0.9387
	F	34	5.161	0.192			
APL	M	32	7.526	0.316	2.5072	64	0.0147
	F	34	7.334	0.308			
APM	M	32	7.170	0.265	0.6646	64	0.5087
	F	34	7.127	0.253			
APN	M	32	4.864	0.342	-0.7821	64	0.4370
	F	34	4.933	0.371			
MLM	M	32	2.796	0.180	0.1315	64	0.8958
	F	34	2.790	0.221			
CFL	M	32	17.817	1.467	1.5144	64	0.1348
	F	34	17.204	1.795			
SML	M	32	23.171	1.554	0.5457	64	0.5872
	F	34	22.991	1.096			
SMB	M	32	23.583	0.921	0.5140	64	0.6090
	F	34	23.450	1.160			
SLS	M	32	27.387	0.941	0.4487	64	0.6552
	F	34	27.264	1.255			
SSL	M	32	10.799	1.234	1.4776	64	0.1444
	F	34	10.397	0.966			
ISL	M	32	15.599	0.938	1.7118	64	0.0918
	F	34	15.204	0.940			
GCB	M	32	3.560	0.166	0.3168	64	0.7524
	F	34	3.546	0.201			
GCH	M	32	5.215	0.371	1.0165	64	0.3132
	F	34	5.124	0.351			
GIL	M	32	28.344	1.517	0.8997	64	0.3717
	F	34	28.001	1.575			
UPL	M	32	42.408	1.506	0.7094	64	0.4807
	F	34	42.131	1.656			
FEB	M	32	8.948	0.306	1.8406	64	0.0703
	F	34	8.807	0.315			
LCS	M	32	3.148	0.281	0.5994	64	0.5510
	F	34	3.010	0.366			
MCS	M	32	2.136	0.107	1.4490	64	0.1522
	F	34	2.095	0.124			

1. Variable definitions may be found in Appendix C
2. No values significant at 0.0012 level.

Table 3. Results of Saguinus oedipus oedipus Students' T-tests for Sexual Dimorphism.

VAR1	SEX	N	MEAN	STD	T	DF	P
HML	M	37	42.904	1.630	0.4673	62	0.6420
	F	27	42.723	1.375			
BUE	M	37	7.764	0.344	-0.0546	62	0.9566
	F	27	7.768	0.324			
RML	M	37	42.904	1.630	0.4673	62	0.6420
	F	27	42.723	1.375			
UML	M	37	52.697	1.781	-0.2981	62	0.7666
	F	27	52.831	1.760			
FML	M	37	64.240	2.658	-1.0580	62	0.2942
	F	27	64.890	2.074			
FTL	M	37	63.866	2.598	-0.8603	62	0.3929
	F	27	64.384	2.046			
TML	M	37	65.207	2.494	-0.6547	62	0.5151
	F	27	65.603	2.231			
BPE	M	37	9.301	0.332	1.0874	62	0.2811
	F	27	9.218	0.252			
BDE	M	37	5.899	0.199	2.1715	62	0.0337
	F	27	5.778	0.245			
BML	M	37	61.909	2.313	-0.6828	62	0.4973
	F	27	62.304	2.243			
MDS	M	37	3.692	0.273	0.2849	62	0.7767
	F	27	3.673	0.244			
MDM	M	37	3.821	0.248	-0.0920	62	0.9270
	F	27	3.826	0.246			
MDH	M	37	6.635	0.277	1.3802	62	0.1725
	F	27	6.535	0.295			
EBR	M	37	10.966	0.502	0.3226	62	0.7481
	F	27	10.927	0.458			
RDH	M	37	4.750	0.206	-0.0437	62	0.9653
	F	27	4.752	0.170			
BOP	M	37	3.721	0.291	0.9206	62	0.3608
	F	27	3.656	0.263			
MBO	M	37	2.650	0.270	-0.0598	62	0.9525
	F	27	2.653	0.235			
WOP	M	37	5.363	0.260	2.0524	62	0.0444
	F	27	5.231	0.246			
ORL	M	37	5.059	0.274	0.7691	62	0.4447
	F	27	5.003	0.304			
OCL	M	37	5.034	0.289	0.6401	62	0.5245
	F	27	4.979	0.401			
APD	M	37	3.816	0.214	-0.9325	62	0.3547
	F	27	3.868	0.230			
MLD	M	37	4.018	0.323	0.6248	62	0.5344
	F	27	3.965	0.347			

Table 3. (Continued).

VAR	SEX	N	MEAN	STD	T	DF	P
APS	M	37	3.858	0.235	0.2987	62	0.7662
	F	27	3.841	0.187			
MLS	M	37	4.138	0.248	0.1138	62	0.9097
	F	27	4.130	0.274			
VHD	M	37	5.815	0.239	-0.8906	62	0.3766
	F	27	5.871	0.264			
HHD	M	37	5.866	0.225	-1.1477	62	0.2555
	F	27	5.937	0.267			
APL	M	37	8.551	0.345	1.7108	62	0.0921
	F	27	8.408	0.307			
APM	M	37	8.181	0.353	0.7426	62	0.4604
	F	27	8.119	0.294			
APN	M	37	5.608	0.426	0.2928	62	0.7706
	F	27	5.580	0.328			
MLM	M	37	3.192	0.272	0.3500	62	0.7275
	F	27	3.170	0.216			
CFL	M	37	17.470	1.324	0.0892	62	0.9292
	F	27	17.442	1.120			
SML	M	37	25.882	1.465	1.5369	58	0.1297
	F	27	25.438	0.831			
SMB	M	37	25.378	0.959	-1.3647	62	0.1773
	F	27	25.694	0.850			
SLS	M	37	29.928	1.048	-0.7979	62	0.4280
	F	27	30.140	1.044			
SSL	M	37	12.723	1.071	2.1679	62	0.0340
	F	27	12.125	1.109			
ISL	M	37	16.468	1.248	1.1029	62	0.2743
	F	27	16.159	0.881			
GCB	M	37	3.827	0.190	0.0923	62	0.9268
	F	27	3.823	0.149			
GCH	M	37	5.622	0.326	1.6318	62	0.1079
	F	27	5.491	0.293			
GIL	M	37	30.288	1.201	0.0178	62	0.9859
	F	27	30.283	0.955			
UPL	M	37	42.960	1.540	-0.4943	62	0.6228
	F	27	43.157	1.630			
FEB	M	37	9.955	0.356	1.0374	62	0.3036
	F	27	9.864	0.337			
LCS	M	37	3.573	0.415	0.5400	62	0.5911
	F	27	3.516	0.421			
MCS	M	37	2.372	0.158	0.6185	62	0.5385
	F	27	2.347	0.163			

1. Variable definitions are provided in Appendix C.

2. No values significant at 0.0012 level.

Of the 130 individuals, in the total sample, 68% were wild born animals and 23% colony born. Students' T-tests were again employed to determine if there were any significant differences between wild versus colony born animals. Results provided in Table 4. and Table 5., indicate that no significant differences exist in the morphological units measured. This confirms the previously reported results of Glassman (1983). Thus colony born and wild born animals were pooled for the bivariate analyses to follow.

Forty-three measurements were taken on all the individuals, and are described and referenced in Appendix C. All measurements were preselected to isolate morphological complexes and to provide information relevant to functional anatomy. Each measurement was taken with a Fowler (digital) Maxi-Cal, and are accurate to 0.001mm.

The data were transformed to natural logarithms, which is a standard transference in allometric studies, thereby reducing the effects of size and indicating rectilinear plots (Gould, 1966; Huxley, 1932). All the subsequent analyses utilize the log-transformed data.

Statistical analyses were performed by Statistical Analysis Systems (SAS) packaged programs (SAS Institute, 1982).

Table 4. Results of Students' T-tests for effect of Colony versus Wild birth for Saguinus fuscicollis illigeri.

VAR1	BORN	N	MEAN	STD	T	DF	P
HML	C	30	47.767	1.672	1.7256	64	0.0892
	W	36	47.091	1.508			
BUE	C	30	7.166	0.321	0.8001	64	0.4266
	W	36	7.105	0.303			
RML	C	30	42.430	1.612	0.5963	64	0.5531
	W	36	42.195	1.567			
UML	C	30	50.457	1.683	0.6896	64	0.4929
	W	36	50.164	1.740			
FML	C	30	59.408	2.257	2.0195	64	0.0476
	W	36	58.321	2.109			
FTL	C	30	59.200	2.267	1.2865	64	0.2029
	W	36	58.500	2.149			
TML	C	30	61.103	2.286	1.7470	64	0.0854
	W	36	60.077	2.449			
BPE	C	30	8.200	0.251	-0.4078	64	0.6848
	W	36	8.226	0.276			
BDE	C	30	5.311	0.207	0.1380	64	0.8906
	W	36	5.304	0.241			
BML	C	30	57.857	2.110	1.2655	64	0.2103
	W	36	57.151	2.371			
MDS	C	30	3.352	0.216	2.3369	64	0.0226
	W	36	3.223	0.209			
MDM	C	30	3.324	0.215	2.0670	64	0.0428
	W	36	3.229	0.157			
MDH	C	30	5.992	0.236	1.5821	64	0.1186
	W	36	5.903	0.223			
EBR	C	30	8.739	0.377	0.8335	64	0.4077
	W	36	8.663	0.359			
RDH	C	30	3.853	0.177	0.3744	64	0.7093
	W	36	3.838	0.146			
BOP	C	30	3.245	0.231	0.1386	64	0.8902
	W	36	3.238	0.172			
MBO	C	30	2.309	0.279	1.1431	47	0.2388
	W	36	2.241	0.177			
WOP	C	30	4.422	0.247	1.2977	64	0.1991
	W	36	4.352	0.189			
ORL	C	30	4.269	0.224	1.5276	64	0.1315
	W	36	4.178	0.251			
OCL	C	30	4.035	0.232	-2.7896	64	0.0069
	W	36	4.179	0.187			
APD	C	30	3.871	0.196	3.8771	64	0.0003*2
	W	36	3.694	0.175			
MLD	C	30	3.583	0.315	-0.5264	64	0.6004
	W	36	3.621	0.264			

Table 4. (Continued).

VAR	BORN	N	MEAN	STD	T	DF	P
APS	C	30	3.532	0.242	0.8762	64	0.3842
	W	36	3.486	0.184			
MLS	C	30	4.012	0.361	1.6899	64	0.0978
	W	36	3.884	0.221			
VHD	C	30	5.185	0.174	2.4711	64	0.0161
	W	36	5.082	0.165			
HHD	C	30	5.233	0.196	2.7851	64	0.0070
	W	36	5.104	0.181			
APL	C	30	7.446	0.296	0.4218	64	0.6746
	W	36	7.412	0.349			
APM	C	30	7.211	0.252	1.8514	64	0.0687
	W	36	7.095	0.254			
APN	C	30	5.006	0.411	2.2995	49	0.0309
	W	36	4.810	0.279			
MLM	C	30	2.851	0.218	2.2261	64	0.0295
	W	36	2.744	0.173			
CFL	C	30	17.647	1.835	0.6496	64	0.5183
	W	36	17.379	1.516			
SML	C	30	23.479	1.169	2.3110	64	0.0241
	W	36	22.744	1.359			
SMB	C	30	23.750	1.149	1.6990	64	0.0942
	W	36	23.318	0.921			
SLS	C	30	27.588	1.284	1.7415	50	0.0877
	W	36	27.104	0.894			
SSL	C	30	10.842	1.008	1.6871	64	0.0964
	W	36	10.384	1.168			
ISL	C	30	15.305	0.910	-0.7037	64	0.4842
	W	36	15.471	0.993			
GCB	C	30	3.567	0.199	0.5668	64	0.5728
	W	36	3.541	0.171			
GCH	C	30	5.159	0.394	-0.1874	64	0.8519
	W	36	5.176	0.336			
GIL	C	30	28.720	1.498	2.7905	64	0.0069
	W	36	27.706	1.447			
UPL	C	30	42.394	1.575	0.6022	64	0.5491
	W	36	42.158	1.596			
FEB	C	30	8.846	0.286	-0.6697	64	0.5054
	W	36	8.899	0.342			
LCS	C	30	3.114	0.404	-0.1850	46	0.8541
	W	36	3.130	0.249			
MCS	C	30	2.096	0.121	-1.2133	64	0.2295
	W	36	2.131	0.111			

1. Variable definitions are provided in Appendix C.

2. Values significant are designated by '*'.

Table 5. Results of Students' T-tests for effect of Colony versus Wild birth for Saguinus oedipus oedipus.

VAR1	BORN	N	MEAN	STD	T	DF	P
HML	C	11	49.322	1.705	-2.0344	62	0.0462
	W	53	50.540	1.826			
BUE	C	11	7.779	0.378	0.1480	62	0.8828
	W	53	7.763	0.045			
RML	C	11	42.018	0.854	-2.9052	26	0.0073
	W	53	42.996	1.577			
UML	C	11	51.810	1.155	-2.0006	62	0.0498
	W	53	52.949	1.807			
FML	C	11	63.348	2.751	-1.7761	62	0.0806
	W	53	64.756	2.318			
FTL	C	11	62.773	2.397	-2.0622	62	0.0434
	W	53	64.357	2.303			
TML	C	11	64.124	2.370	-1.9605	62	0.0544
	W	53	65.633	2.315			
BPE	C	11	9.240	0.370	-0.3129	62	0.7554
	W	53	9.272	0.289			
BDE	C	11	5.875	0.262	0.4290	62	0.6694
	W	53	5.842	0.120			
BML	C	11	60.925	2.454	-1.8825	62	0.0645
	W	53	62.315	2.183			
MDS	C	11	3.808	0.200	1.7722	62	0.0813
	W	53	3.658	0.264			
MDM	C	11	3.770	0.175	-0.7847	62	0.4356
	W	53	3.834	0.257			
MDH	C	11	6.683	0.144	1.7993	32	0.0814
	W	53	6.574	0.306			
EBR	C	11	11.002	0.623	0.3936	62	0.6952
	W	53	10.939	0.452			
RDH	C	11	4.734	0.177	-0.3232	62	0.7477
	W	53	4.754	0.194			
BOP	C	11	3.690	0.217	-0.0506	62	0.9598
	W	53	3.695	0.292			
MBO	C	11	2.537	0.198	-1.6553	62	0.1029
	W	53	2.675	0.260			
WOP	C	11	5.301	0.234	-0.0914	62	0.9275
	W	53	5.309	0.268			
ORL	C	11	5.068	0.226	0.4122	62	0.6816
	W	53	5.028	0.298			
OCL	C	11	5.074	0.348	0.6730	62	0.5034
	W	53	4.998	0.339			
APD	C	11	4.003	0.256	2.8695	62	0.0056
	W	53	3.804	0.199			
MLD	C	11	4.092	0.327	1.0606	62	0.2930
	W	53	3.975	0.332			

Table 5. (Continued).

VAR	BORN	N	MEAN	STD	T	DF	P
MLS	C	11	4.258	0.225	1.7801	62	0.0800
	W	53	4.109	0.258			
VHD	C	11	5.935	0.318	1.4213	62	0.1602
	W	53	5.819	0.232			
HHD	C	11	6.015	0.320	1.8195	62	0.0737
	W	53	5.871	0.221			
APL	C	11	8.397	0.324	-1.0133	62	0.3148
	W	53	8.510	0.337			
APM	C	11	8.101	0.296	-0.5898	62	0.5575
	W	53	8.165	0.337			
APN	C	11	5.840	0.347	2.3918	62	0.0198
	W	53	5.547	0.376			
MLM	C	11	3.302	0.252	1.7758	62	0.0807
	W	53	3.158	0.243			
CFL	C	11	17.867	1.220	1.2130	62	0.2297
	W	53	17.374	1.230			
SML	C	11	25.553	0.620	-0.6533	33	0.5181
	W	53	25.725	1.346			
SMB	C	11	25.426	1.057	-0.3353	62	0.7386
	W	53	25.529	0.901			
SLS	C	11	29.572	1.174	-1.5756	62	0.1202
	W	53	30.110	1.001			
SSL	C	11	12.450	0.905	-0.0641	62	0.9491
	W	53	12.474	1.166			
ISL	C	11	15.973	1.174	-1.2009	62	0.2344
	W	53	16.413	1.094			
GCB	C	11	3.810	0.192	-0.3210	62	0.7493
	W	53	3.828	0.170			
GCH	C	11	5.436	0.185	-2.1923	26	0.0375
	W	53	5.595	1.140			
GIL	C	11	30.017	0.841	-0.8905	62	0.3766
	W	53	30.341	1.140			
UPL	C	11	42.235	1.171	-1.9168	62	0.0599
	W	53	43.211	1.597			
FEB	C	11	9.735	0.412	-1.9353	62	0.0575
	W	53	9.954	0.326			
LCS	C	11	3.577	0.373	0.2473	62	0.8055
	W	53	3.543	0.426			
MCS	C	11	2.310	0.171	-1.1804	62	0.2424
	W	53	2.372	0.157			

1. Variable definitions are provided in Appendix C.

2. No values significant at 0.0012 level.

Procedures utilized included PROC T-TEST for the tests of significance, and PROC GLM (General Linear Models) for the least-squares regressions. Reduced major axis regression analyses were derived according to the formulae provided by Sokal and Rohlf (1981). The foremost statistical technique utilized in allometric studies is the bivariate regression. The allometric baseline used in morphological and ecological studies is the regression line itself (Gould, 1975, 1978). Various methods exist in the literature for bivariate regression. Pilbeam and Gould (1974) recommend the use of reduced major axis methods in allometric research. This method does not assume an independent-dependent relationship between the variables under examination. Furthermore, measurement error is assumed for both the X and Y variables (Sokal and Rohlf, 1981:549-550). Reduced major axis methods are best for the analysis of structural/ functional relationships between variables, and this method will be utilized for the interpretation of the results present in this study.

CHAPTER V

RESULTS AND DISCUSSION

Students' T-Tests comprise the initial examination of the postcranial variation between Saguinus oedipus oedipus and Saguinus fuscicollis illigeri. These were utilized to determine whether there were significant differences between the measurements for each species. Results of these tests indicate that there is a statistically significant difference between the means for virtually all of the 43 measurements for the two species, with S.oedipus oedipus being the larger in all cases. The results of these tests are provided in Table 6. Since significant differences were observed between the two species, a "bone by bone" bivariate regression analysis was undertaken utilizing the reduced major axis method. The measures representing width and breadth for each bone were regressed on the maximum length of the bone from which they were taken. The measures of width and breadth, representing robusticity, were regressed in this manner to explore the relationship between greater bone size and robusticity. It was hoped that a comparison such as this would elucidate the allometric relationship between shape and size in a manageable fashion. Only those plots whose variables expressed an r value of 0.5 for at least one of the two species is described (Wolpoff, 1985).

Table 6. Results of Students' T-Tests for species differences between Saguinus oedipus oedipus and Saguinus fuscicollis illigeri

VAR1	SPECIES	N	MEAN	STD	T	DF	P
HML	S.f.i.	66	47.398	1.608	-9.6503	128	0.0001*2
	S.o.o.	64	50.330	1.851			
BUE	S.f.i.	66	7.133	0.311	-11.2100	128	0.0001*
	S.o.o.	64	7.765	0.333			
RML	S.f.i.	66	42.302	1.580	-1.9349	128	0.0552
	S.o.o.	64	42.828	1.519			
UML	S.f.i.	66	50.297	1.707	-8.0789	128	0.0001*
	S.o.o.	64	52.753	1.759			
FML	S.f.i.	66	58.815	2.228	-13.9351	128	0.0001*
	S.o.o.	64	64.514	2.433			
FTL	S.f.i.	66	58.818	2.214	-13.0738	128	0.0001*
	S.o.o.	64	64.085	2.377			
TML	S.f.i.	66	60.543	2.414	-11.4947	128	0.0001*
	S.o.o.	64	65.376	2.376			
BPE	S.f.i.	66	8.214	0.263	-21.1927	128	0.0001*
	S.o.o.	64	9.266	0.302			
BDE	S.f.i.	66	5.307	0.225	-13.6931	128	0.0001*
	S.o.o.	64	5.848	0.226			
BML	S.f.i.	66	57.472	2.227	-11.5610	128	0.0001*
	S.o.o.	64	62.076	2.274			
MDS	S.f.i.	66	3.285	0.219	-9.4865	128	0.0001*
	S.o.o.	64	3.684	0.259			
MDM	S.f.i.	66	3.272	0.190	-14.3425	128	0.0001*
	S.o.o.	64	3.823	0.245			
MDH	S.f.i.	66	5.943	0.231	-14.2355	128	0.0001*
	S.o.o.	64	6.593	0.287			
EBR	S.f.i.	66	8.697	0.366	-29.9783	117	0.0001*
	S.o.o.	64	10.950	0.481			
RDH	S.f.i.	66	3.845	0.160	-29.4413	128	0.0001*
	S.o.o.	64	4.751	0.190			
BOP	S.f.i.	66	3.241	0.200	-10.6227	113	0.0001*
	S.o.o.	64	3.694	0.279			
MBO	S.f.i.	66	2.272	0.230	-8.9321	128	0.0001*
	S.o.o.	64	2.651	0.254			
WOP	S.f.i.	66	4.384	0.218	-21.9221	128	0.0001*
	S.o.o.	64	5.308	0.261			
ORL	S.f.i.	66	4.219	0.242	-17.5967	128	0.0001*
	S.o.o.	64	5.308	0.286			
OCL	S.f.i.	66	4.114	0.219	-17.8594	107	0.0001*
	S.o.o.	64	5.011	0.339			
APD	S.f.i.	66	3.775	0.203	-1.7034	128	0.0909
	S.o.o.	64	3.838	0.221			
MLD	S.f.i.	66	3.604	0.287	-7.2053	128	0.0001*
	S.o.o.	64	3.995	0.332			

Table 6. (Continued).

VAR	SPECIES	N	MEAN	STD	T	DF	P
APS	S.f.i.	66	3.507	0.211	-9.2006	128	0.0001*
	S.o.o.	64	3.851	0.215			
MLS	S.f.i.	66	3.942	0.297	-3.9373	128	0.0001*
	S.o.o.	64	4.135	0.257			
VHD	S.f.i.	66	5.129	0.176	-18.8104	128	0.0001*
	S.o.o.	64	5.839	0.250			
HHD	S.f.i.	66	5.162	0.197	-18.8618	128	0.0001*
	S.o.o.	64	5.896	0.244			
APL	S.f.i.	66	7.427	0.324	-18.4024	128	0.0001*
	S.o.o.	64	8.490	0.335			
APM	S.f.i.	66	7.148	0.258	-19.4672	128	0.0001*
	S.o.o.	64	8.154	0.329			
APN	S.f.i.	66	4.900	0.357	-10.7124	128	0.0001*
	S.o.o.	64	5.600	0.385			
MLM	S.f.i.	66	2.793	0.201	-9.8621	128	0.0001*
	S.o.o.	64	3.183	0.248			
CFL	S.f.i.	66	17.501	1.661	0.1671	119	0.8676
	S.o.o.	64	17.458	1.233			
SML	S.f.i.	66	23.078	1.330	-11.5568	128	0.0001*
	S.o.o.	64	25.695	1.249			
SMB	S.f.i.	66	23.514	1.045	-11.5444	128	0.0001*
	S.o.o.	64	25.512	0.921			
SLS	S.f.i.	66	27.323	1.107	-14.2714	128	0.0001*
	S.o.o.	64	30.018	1.043			
SSL	S.f.i.	66	10.592	1.114	-9.5890	128	0.0001*
	S.o.o.	64	12.470	1.119			
ISL	S.f.i.	66	15.396	0.953	-5.1935	128	0.0001*
	S.o.o.	64	16.338	1.111			
GCB	S.f.i.	66	3.553	0.183	-8.7249	128	0.0001*
	S.o.o.	64	3.825	0.173			
GCH	S.f.i.	66	5.168	0.361	-6.6642	128	0.0001*
	S.o.o.	64	5.568	0.318			
GIL	S.f.i.	66	28.167	1.545	-9.0382	117	0.0001*
	S.o.o.	64	30.285	1.096			
UPL	S.f.i.	66	42.265	1.579	-2.8185	128	0.0001*
	S.o.o.	64	43.043	1.568			
FEB	S.f.i.	66	8.875	0.316	-17.8617	128	0.0001*
	S.o.o.	64	9.917	0.348			
LCS	S.f.i.	66	3.123	0.326	-6.5180	128	0.0001*
	S.o.o.	64	3.549	0.415			
MCS	S.f.i.	66	2.115	0.117	-10.0295	128	0.0001*
	S.o.o.	64	2.362	0.160			

1. Variable definitions are found in Appendix C

2. Values significant are designated by '*'.

In every case, the intraspecific slopes were compared with the Z-statistic described in chapter III. The null hypothesis, to reiterate, was that the slopes were not significantly different (at 0.05). If such a case existed where the slopes of the species were not significantly different, then the bivariate plots were examined and the differences assessed qualitatively (McKinney, 1984). The reduced major axis statistics for the individual width and breadth measurements regressed on the bone from which they derive are presented in Table 7. Correlations for the variable pairs may be found in Table 8.

The reduced major axis slopes for the breadth of the upper epiphysis (LBUE) of the humerus for S.o.oedipus and S.f.illigeri are 1.162 and 1.281, respectively. The 95% confidence intervals show that neither slope is significantly different from isometry (1.0). The Z-statistic indicates that the intraspecific slopes are not significantly different. A qualitative examination of the plots (Figure 4.) indicates that the S.o.oedipus regression line is less steep than that for S.f.illigeri. In this example, it may be possible to argue for neoteny, meaning that S.f.illigeri is growing at a faster rate than S.o.oedipus.

Table 7. Reduced Major Axis regression statistics for individual width and breadth measurements on the bone from which they derive. Slopes and intercepts are represented by k and b, respectively.

SPECIES	VAR1	k	Sek0	CI2	Z3	b
S.f.i.	LBUE/LHML	1.281	0.148	0.985-1.577		-2.977
S.o.o.	LBUE/LHML	1.162	0.117	0.928-1.394	0.859	-2.502
S.f.i.	LMDS/LHML	1.952	0.221	1.510-2.394		-6.343
S.o.o.	LMDS/LHML	1.906	0.225	1.456-2.355	0.169	-6.165
S.f.i.	LMDM/LHML	1.708	0.194	1.321-2.096		-5.394
S.o.o.	LMDM/LHML	1.738	0.201	1.337-2.139	-0.125	-5.471
S.f.i.	LMDH/LHML	1.153	0.135	0.882-1.424		-2.666
S.o.o.	LMDH/LHML	1.179	0.144	0.891-1.467	-0.164	-2.735
S.f.i.	LEBR/LHML	1.228	0.130	0.969-1.487		-2.577
S.o.o.	LEBR/LHML	1.190	0.134	0.922-1.459	0.254	-2.270
S.f.i.	LLCS/LHML	2.945	0.352	2.242-3.648		-10.228
S.o.o.	LLCS/LHML	3.007	0.376	2.256-3.758	-0.124	-10.520
S.f.i.	LBOP/LUML	1.820	0.218	1.383-2.256		-5.954
S.o.o.	LBOP/LUML	2.211	0.240	1.731-2.691	-1.362	-7.463
S.f.i.	LMBO/LUML	2.876	0.350	2.176-3.576		-10.450
S.o.o.	LMBO/LUML	2.844	0.338	2.169-3.520	-0.069	-10.307
S.f.i.	LWOP/LUML	1.462	0.177	1.107-1.817		-4.251
S.o.o.	LWOP/LUML	1.477	0.158	1.161-1.793	-0.080	-4.189
S.f.i.	LORL/LUML	1.690	0.202	1.287-2.094		-5.183
S.o.o.	LORL/LUML	1.702	0.187	1.328-2.077	-0.053	-5.135
S.f.i.	LOCL/LUML	1.563	0.187	1.190-1.936		-4.710
S.o.o.	LOCL/LUML	2.069	0.232	1.605-2.534	-1.896	-6.595
S.f.i.	LUPL/LUML	1.103	0.038	1.026-1.180		-0.577
S.o.o.	LUPL/LUML	1.091	0.044	1.003-1.179	0.271	-0.563
S.f.i.	LRDH/LRML	1.117	0.130	0.856-1.377		-2.835
S.o.o.	LRDH/LRML	1.139	0.116	0.907-1.370	-0.165	-2.720
S.f.i.	LMCS/LRML	1.471	0.156	1.160-1.783		-4.761
S.o.o.	LMCS/LRML	1.902	0.058	1.464-2.341	-1.770	-6.290
S.f.i.	LSMB/LSML	0.774	0.085	0.605-0.944		0.728
S.o.o.	LSMB/LSML	0.736	0.078	0.580-0.892	0.446	0.849
S.f.i.	LSLS/LSML	0.708	0.078	0.552-0.865		1.085
S.o.o.	LSLS/LSML	0.708	0.075	0.557-0.858	0.008	1.105
S.f.i.	LSSL/LSML	1.812	0.177	1.458-2.166		-3.330
S.o.o.	LSSL/LSML	1.817	0.189	1.440-2.194	-0.024	-3.378
S.f.i.	LISL/LSML	1.071	0.098	0.876-1.226		-0.629
S.o.o.	LISL/LSML	1.386	0.116	1.154-1.619	-2.505*	-0.606
S.f.i.	LGCB/LSML	0.884	0.094	0.696-1.071		-1.507
S.o.o.	LGCB/LSML	0.922	0.104	0.714-1.131	-0.343	-1.653
S.f.i.	LGCH/LSML	1.199	0.144	0.909-1.490		-2.123
S.o.o.	LGCH/LSML	1.138	0.133	0.872-1.404	0.397	-1.979
S.f.i.	LGIL/LSML	0.958	0.087	0.297-1.619		0.331
S.o.o.	LGIL/LSML	0.742	0.058	0.626-0.858	3.298*	1.000

Table 7. (Continued).

SPECIES	VAR1	k	Sek0	CI2	Z3	b
S.f.i. LHHD/LFML		1.008	0.190	0.790-1.226		-2.645
S.o.o. LHHD/LFML		1.078	0.180	0.862-1.294	-0.587	-2.719
S.f.i. LFTL/LFML		0.998	0.025	0.948-1.047		0.009
S.o.o. LFTL/LFML		0.982	0.021	0.940-1.025	0.705	0.067
S.f.i. LVHD/LFML		0.898	0.094	0.710-1.086		-2.024
S.o.o. LVHD/LFML		1.114	0.116	0.882-1.346	-1.730	-2.877
S.f.i. LFEB/LFML		0.947	0.180	0.730-1.163		-1.675
S.o.o. LFMB/LFML		0.931	0.090	0.750-1.111	0.158	-1.585
S.f.i. LAPD/LFML		1.404	0.160	1.085-1.724		-4.393
S.o.o. LAPD/LFML		1.500	0.184	1.132-1.868	-0.458	-4.906
S.f.i. LMLD/LFML		2.040	0.236	1.567-2.512		-7.030
S.o.o. LMLD/LFML		2.142	0.250	1.642-2.642	-0.333	-7.541
S.f.i. LAPS/LFML		1.569	0.170	1.229-1.909		-5.569
S.o.o. LAPS/LFML		1.446	0.167	1.111-1.780	0.629	-4.675
S.f.i. LAPL/LFML		1.157	0.129	0.898-1.416		-2.710
S.o.o. LAPL/LFML		1.034	0.099	0.836-1.232	1.066	-2.170
S.f.i. LAPM/LFML		0.950	0.100	0.750-1.150		-1.901
S.o.o. LAPM/LFML		1.062	0.109	0.844-1.279	-0.943	-2.325
S.f.i. LAPN/LTML		1.784	0.204	1.377-2.192		-5.734
S.o.o. LAPN/LTML		1.879	0.206	1.467-2.291	-0.382	-6.133
S.f.i. LMLM/LTML		1.804	0.194	1.415-2.193		-6.377
S.o.o. LMLM/LTML		2.116	0.255	1.606-2.626	-1.064	-7.688
S.f.i. LCFL/LTML		2.393	0.276	1.840-2.945		-6.959
S.o.o. LCFL/LTML		1.918	0.207	1.504-2.331	1.678	-5.157
S.f.i. LBPE/LTML		0.809	0.081	0.647-0.970		-1.213
S.o.o. LBPE/LTML		0.897	0.088	0.720-1.073	-0.926	-1.522
S.f.i. LBDE/LTML		1.059	0.122	0.815-1.303		-2.676
S.o.o. LBDE/LTML		1.062	0.114	0.834-1.290	-0.027	-2.674

1. Variable definitions are found in Appendix C.

2. CI, Confidence Interval 95%.

3. Z, Significance indicated by '*' ($P > 0.05$).

Table 8. Correlations for the variable pairs.

SPECIES	VAR1	r	P	SPECIES	VAR	r	P
S.f.i.	LBUE/LHML	.35	.0045	S.f.i.	LISL/LSML	.67	.0001*
S.o.o.	LBUE/LHML	.60	.0001* ²	S.o.o.	LISL/LSML	.74	.0001*
S.f.i.	LMDS/LHML	.40	.0012	S.f.i.	LGCH/LSML	.20	.1190
S.o.o.	LMDS/LHML	.33	.0074	S.o.o.	LGCH/LSML	.40	.0025
S.f.i.	LMDM/LHML	.41	.0012	S.f.i.	LGCB/LSML	.51	.0001*
S.o.o.	LMDM/LHML	.40	.0018	S.o.o.	LGCB/LSML	.43	.0004
S.f.i.	LMDH/LHML	.31	.0150	S.f.i.	LGIL/LSML	.67	.0001*
S.o.o.	LMDH/LHML	.22	.0856	S.o.o.	LGIL/LSML	.78	.0001*
S.f.i.	LEBR/LHML	.52	.0001*	S.f.i.	LFTL/LFML	.98	.0001*
S.o.o.	LEBR/LHML	.43	.0004	S.o.o.	LFTL/LFML	.98	.0001*
S.f.i.	LLCS/LHML	.24	.0496	S.f.i.	LVHD/LFML	.53	.0001*
S.o.o.	LLCS/LHML	-.04	.7539	S.o.o.	LVHD/LFML	.55	.0001*
S.f.i.	LBOP/LUML	.23	.0658	S.f.i.	LHHD/LFML	.50	.0001*
S.o.o.	LBOP/LUML	.51	.0001*	S.o.o.	LHHD/LFML	.61	.0001*
S.f.i.	LMBO/LUML	.15	.2303	S.f.i.	LFEB/LFML	.41	.0025
S.o.o.	LMBO/LUML	.31	.0122	S.o.o.	LFEB/LFML	.63	.0001*
S.f.i.	LWOP/LUML	.17	.1719	S.f.i.	LAPD/LFML	.40	.0016
S.o.o.	LWOP/LUML	.52	.0001*	S.o.o.	LAPD/LFML	.21	.1352
S.f.i.	LORL/LUML	.25	.0461	S.f.i.	LMLD/LFML	.34	.0055
S.o.o.	LORL/LUML	.51	.0001*	S.o.o.	LMLD/LFML	.36	.0037
S.f.i.	LOCL/LUML	.24	.0486	S.f.i.	LAPS/LFML	.50	.0001*
S.o.o.	LOCL/LUML	.44	.0003	S.o.o.	LAPS/LFML	.41	.0021
S.f.i.	LUPL/LUML	.80	.0001*	S.f.i.	LAPL/LFML	.42	.0005
S.o.o.	LUPL/LUML	.95	.0001*	S.o.o.	LAPL/LFML	.64	.0001*
S.f.i.	LRDH/LRML	.32	.0093	S.f.i.	LAPM/LFML	.52	.0001*
S.o.o.	LRDH/LRML	.60	.0001*	S.o.o.	LAPM/LFML	.57	.0001*
S.f.i.	LMCS/LRML	.51	.0001*	S.f.i.	LAPN/LTML	.40	.0020
S.o.o.	LMCS/LRML	.41	.0017	S.o.o.	LAPN/LTML	.50	.0001*
S.f.i.	LSMB/LSML	.51	.0001*	S.f.i.	LMLM/LTML	.50	.0001*
S.o.o.	LSMB/LSML	.53	.0001*	S.o.o.	LMLM/LTML	.30	.0347
S.f.i.	LSLS/LSML	.44	.0002	S.f.i.	LCFL/LTML	.35	.0042
S.o.o.	LSLS/LSML	.53	.0001*	S.o.o.	LCFL/LTML	.51	.0001*
S.f.i.	LSSL/LSML	.61	.0001*	S.f.i.	LBPE/LTML	.60	.0001*
S.o.o.	LSSL/LSML	.61	.0001*	S.o.o.	LBPE/LTML	.62	.0001*
S.f.i.	LISL/LSML	.70	.0001*	S.f.i.	LBDE/LTML	.40	.0040
S.o.o.	LISL/LSML	.74	.0001*	S.o.o.	LBDE/LTML	.51	.0001*

1. Variable definitions are found in Appendix C.

2. Values significant are designated by '*'.

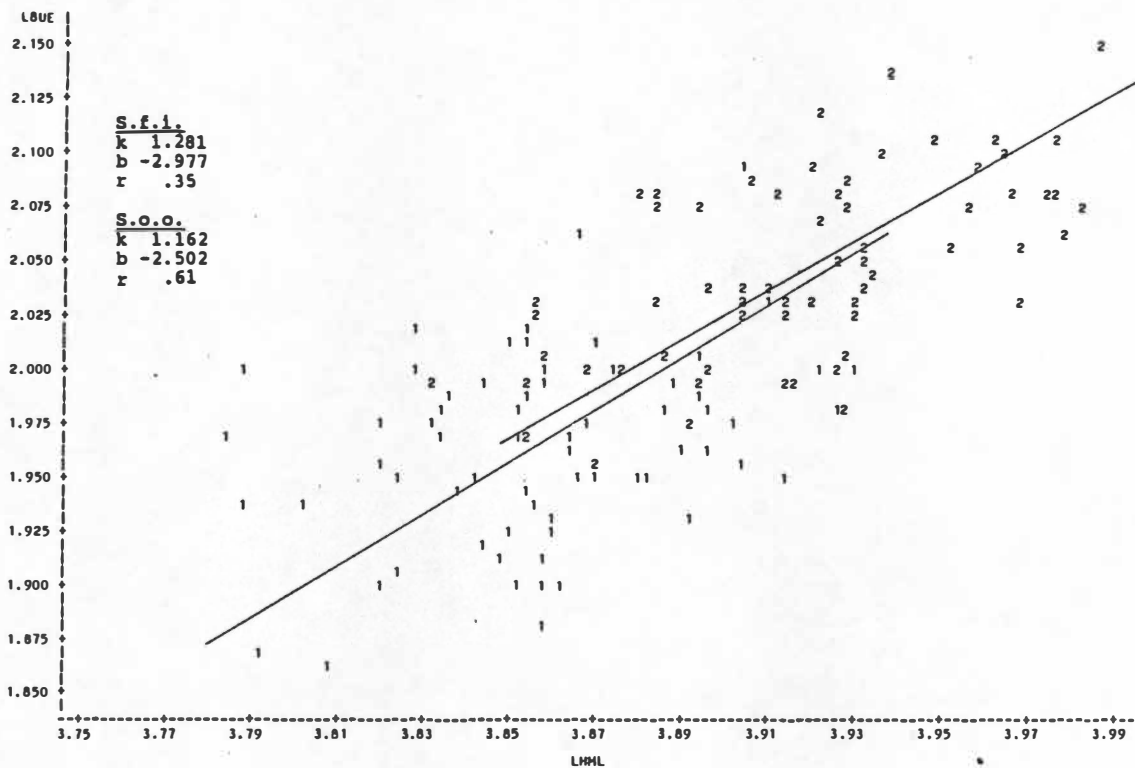


Figure 4. Reduced Major Axis regressions for the breadth of the upper epiphysis of the humerus (LBUE) on the maximum length of the humerus (LHML). In this, and all plots to follow, Saguinus fuscicollis and Saguinus oedipus are represented by 1's and 2's, respectively.

The reduced major axis slopes for the epicondylar breadth of the humerus (LEBR) for S.o.oedipus and S.f.illigeri are 1.190 and 1.228, respectively. The 95% confident interval indicates that neither slope is significantly different from isometry (1.0). The Z-statistic indicates that the intraspecific slopes are not significantly different. An examination of the plots (Figure 5.) reveals that the regression line for S.o.oedipus is pre-displaced above S.f.illigeri. The reduced major axis slopes for the breadth of the olecranon process (LBOP) of the ulna for S.o.oedipus and S.f.illigeri are 2.211 and 1.820, respectively. The 95% confidence interval indicates that both slopes are significantly different from isometry (1.0), positively allometric. The Z-statistic reveals that the slopes are not significantly different. A visual examination of the plots (Figure 6.) indicates that the regression lines for S.f.illigeri and S.o.oedipus are nearly identical, suggesting a case of hypermorphosis. Rather, S.o.oedipus is merely an "overgrown" S.f.illigeri possibly resulting from a delayed sexual maturation.

The reduced major axis slopes for the maximum width of the olecranon process (LWOP) for S.o.oedipus and S.f.illigeri are 1.477 and 1.462, respectively.

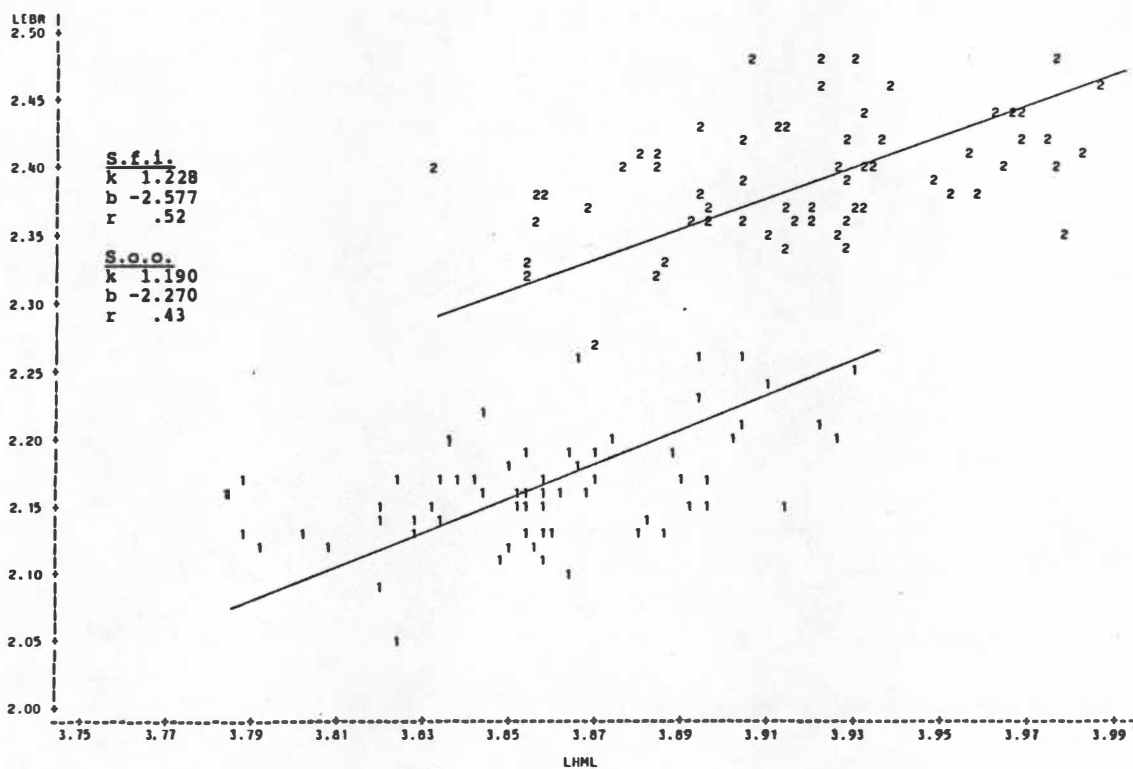


Figure 5. Reduced Major Axis regressions for the epicondylar breadth of the humerus (LEBR) on the maximum length of the humerus (LHML).

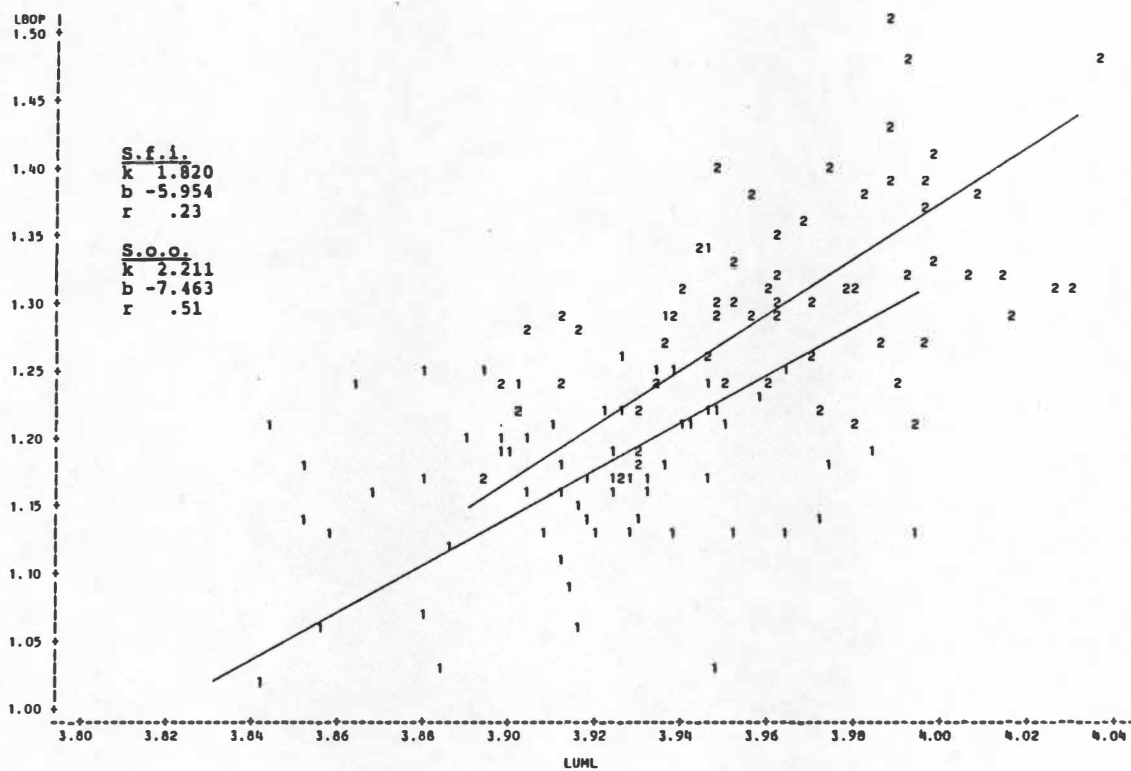


Figure 6. Reduced Major Axis regressions for maximum breadth of the olecranon process (LBOP) on the maximum length of the ulna (LUML).

The 95% confidence interval indicates that both slopes are significantly different from isometry (1.0). They are positively allometric. The Z-statistic indicates that there is no significant difference between the slopes of the two groups. A visual examination of the plots (Figure 7.) reveal that the regression lines for S.o.oedipus are pre-displaced above those for S.f.illigeri, possibly indicating a transposition, which is necessary to preserve the function of the morphological structure.

The reduced major axis slopes for the olecranon process to radial notch length (LORL) of the ulna for S.o.oedipus and S.f.illigeri are 1.702 and 1.690, respectively. The 95% confidence interval suggests that the slopes for the two groups are significantly different from isometry (1.0). The Z-statistic indicates that neither slope is significantly different from each other. A qualitative examination of the plots (Figure 8.) reveals that the regression lines for S.o.oedipus are pre-displaced above those for S.f.illigeri. As in the case above, the increase in size of the olecranon process in S.o.oedipus, relative to S.f.illigeri, does not necessarily indicate a change in function of this morphological structure.

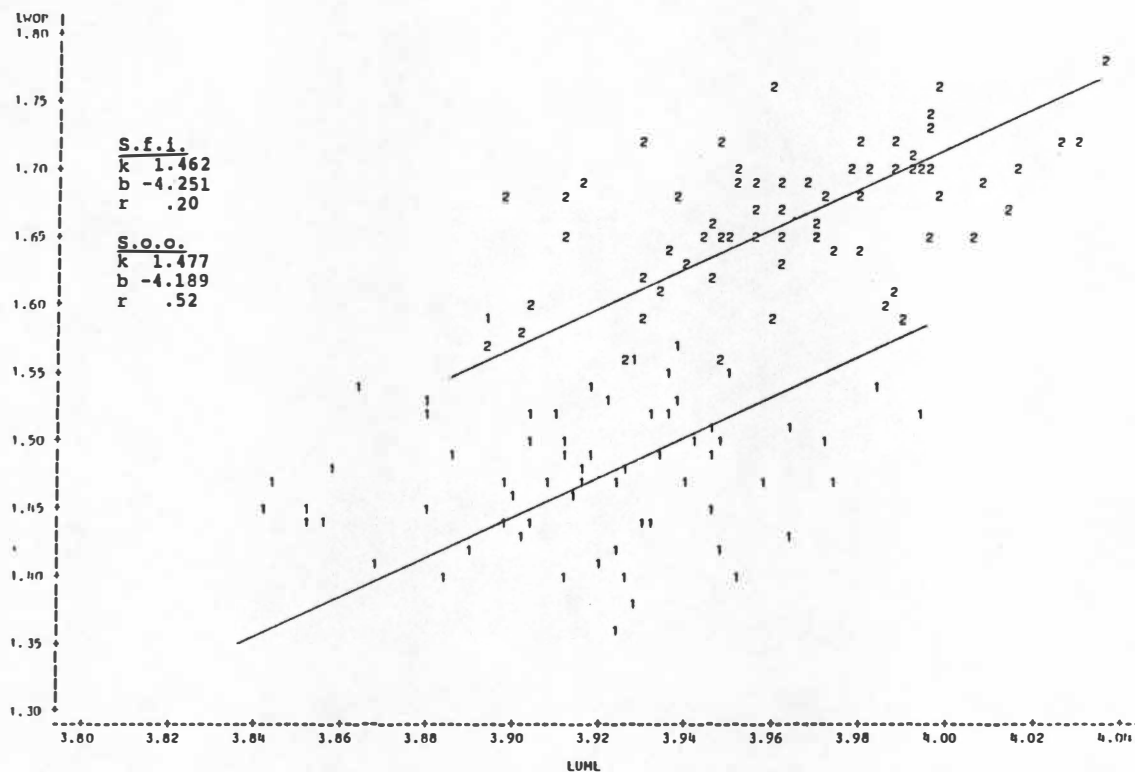


Figure 7. Reduced Major Axis regressions for the maximum width of the olecranon process (WOP) on the maximum length of the ulna (LUML).

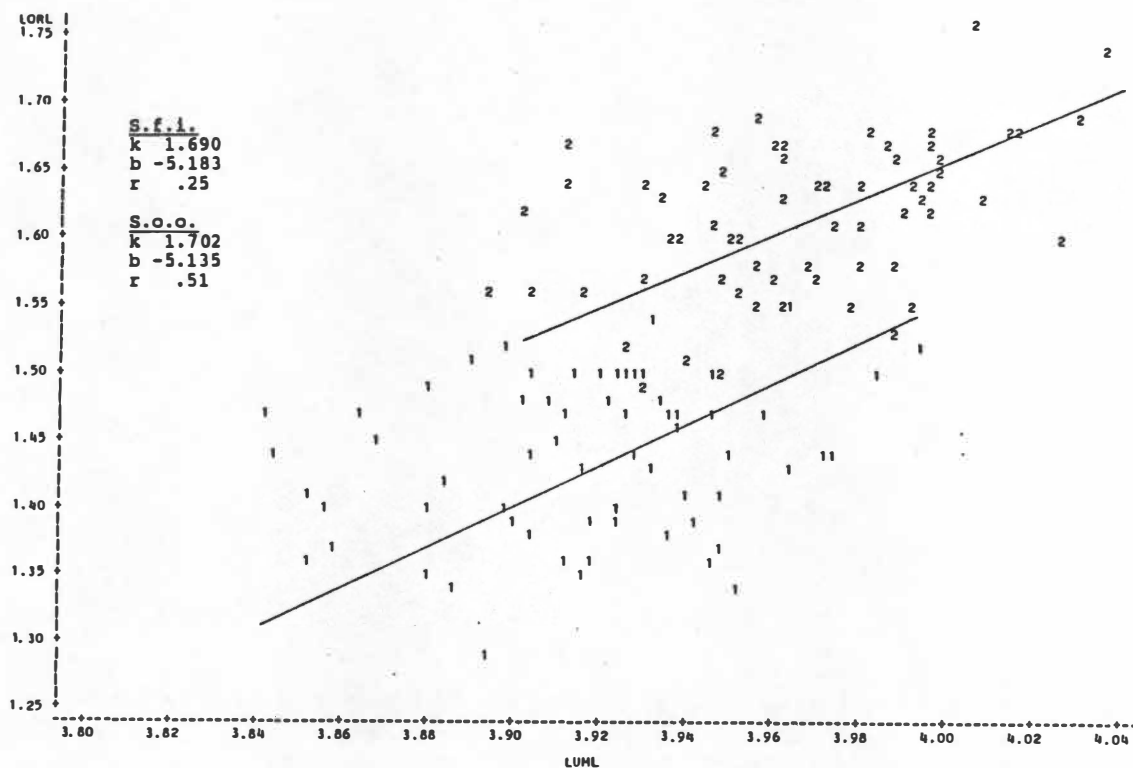


Figure 8. Reduced Major Axis regressions for the olecranon process to radial notch length (ORL) on the maximum length of the ulna (LUML).

The reduced major axis slopes for the maximum diameter of the head (LRDH) of the radius for S.o.oedipus and S.f.illigeri are 1.139 and 1.117, respectively. The 95% confident interval reveals that neither slope is significantly different from isometry (1.0). The Z-statistic reveals that neither slope is significantly different from each other. The visual examination of the plots (Figure 9.) indicates that the regression lines for S.o.oedipus are pre-displaced above those of S.f.illigeri. In this case, the pre-displacement, or transposition, is probably necessary to retain the function of the radius head for rotation and muscle attachment at a larger size.

The reduced major axis slopes for the maximum circumference of the shaft (LMCS) of the radius for S.o.oedipus and S.f.illigeri are 1.902 and 1.417, respectively. The 95% confident interval indicates that both slopes are significantly different from isometry (1.0). The Z-statistic reveals that the slopes are not significantly different from each other.

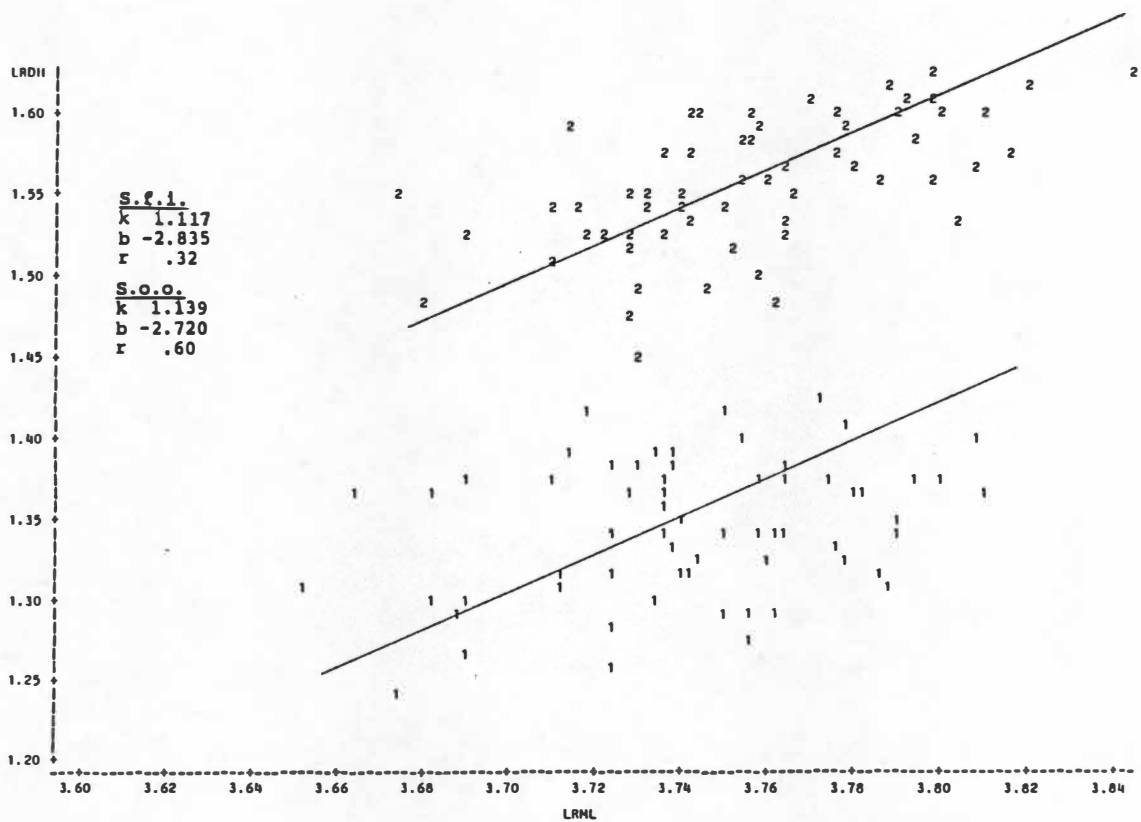


Figure 9. Reduced Major Axis regressions for the maximum diameter of the radius head (LRDH) on the maximum length of the radius (LRML).

A qualitative examination of the plots (Figure 10.) indicates the the regression lines for S.o.oedipus are more positively allometric (steeper) than those of S.f.illigeri, thereby revealing a case of acceleration. This may be due to a rapid increase of growth in S.o.oedipus relative to S.f.illigeri.

The reduced major axis slopes for scapula maximum breadth (LSMB) for S.o.oedipus and S.f.illigeri are 0.736 and 0.774, respectively. The confidence interval indicates that both slopes are significantly different from isometry (1.0). The resulting conclusion from examination of the confidence interval may be that larger animals (S.o.oedipus) have differently shaped scapula than do the smaller ones. The Z-statistic reveals that the slopes are not significantly different from each other. A visual examination of the plots (Figure 11.) indicates that the regression lines for S.o.oedipus are similar to those for S.f.illigeri. In this case, the term hypermorphosis is used to describe the condition where S.o.oedipus is a geometrically larger S.f.illigeri. The variability, in this case for the larger species is merely an extension of that present in the smaller species.

The reduced major axis slopes for the length of the spine (LSLS) of the scapula for S.o.oedipus and S.f.illigeri are 0.708 and 0.708, respectively.

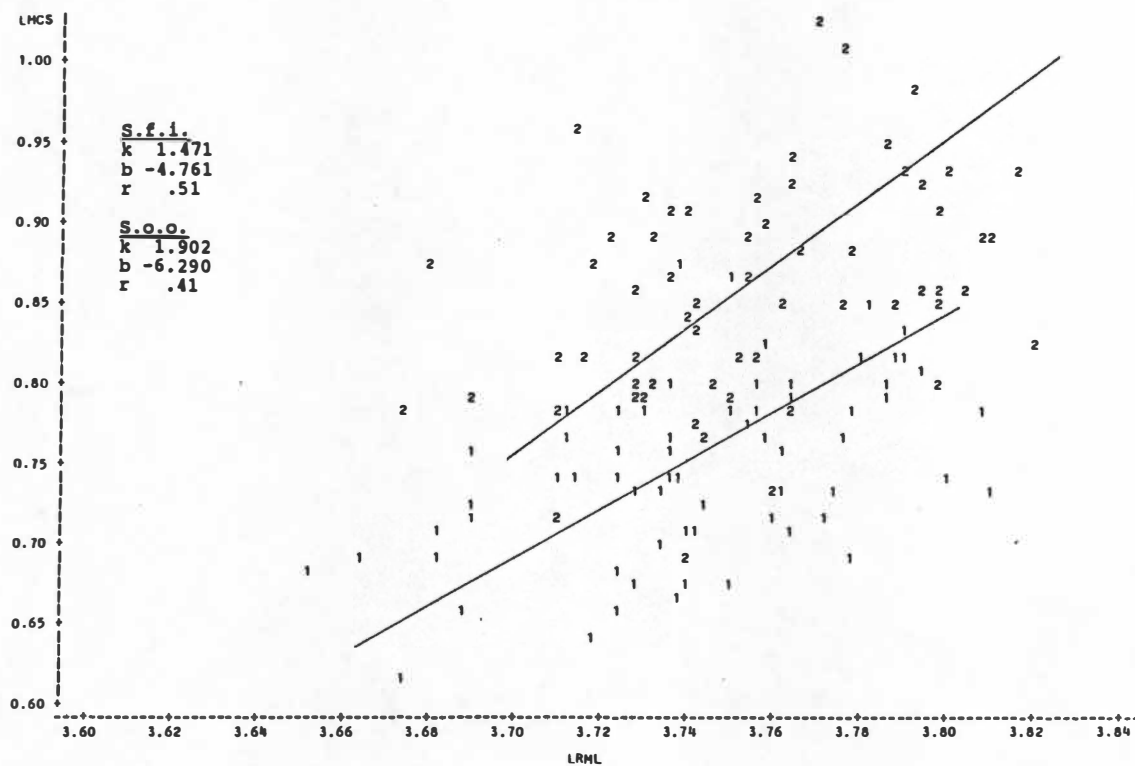


Figure 10. Reduced Major Axis regressions for the maximum circumference of the shaft of the radius (LMCS) on the maximum length of the radius (LRML).

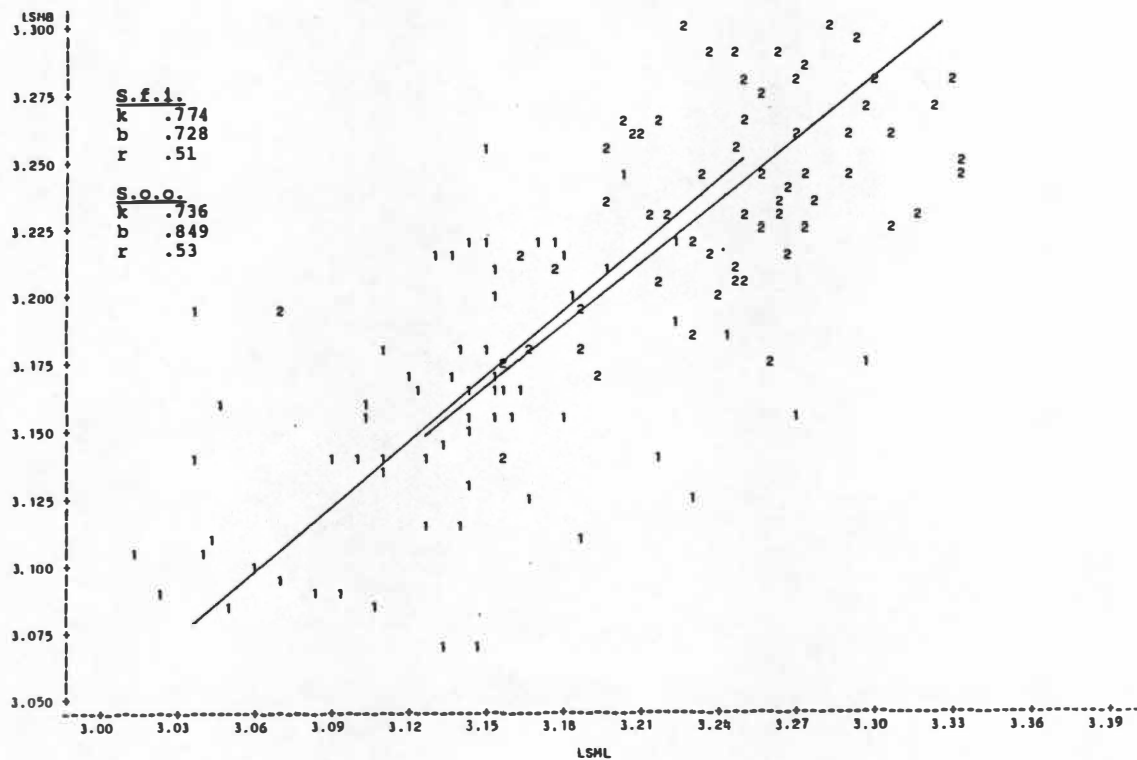


Figure 11. Reduced Major Axis regressions for the maximum breadth of the scapula (LSMB) on the maximum length of the scapula (LSML).

The 95% confidence interval indicates that both slopes are significantly different from isometry (1.0). The difference in this case is quite similar to the one above. This is probably due to the relationship between shape and the subsequent increase in size of the scapula. The Z-statistic reveals that neither slope is significantly different from each other. The regression lines for S.o.oedipus, after a qualitative examination of the plots (Figure 12.), and S.f.illigeri are identical. Further viewing reveals that S.o.oedipus is merely an extension of S.f.illigeri, and exhibits those properties best explained by hypermorphosis.

The reduced major axis slopes for the length of the supra-spinous line (LSSL) of the scapula for S.o.oedipus and S.f.illigeri are 1.817 and 1.812, respectively. The 95% confidence interval indicates that, in this case, both slopes are significantly different from isometry (1.0). The Z-statistic assures that each slope is not significantly different from each other. A visual interpretation of the plots (Figure 13.) indicates that the regression lines for S.o.oedipus are post-displaced above those for S.f.illigeri. The post-displacement is probably best described as S.o.oedipus retaining the functional ability of the supra-spinous line for muscle attachment, as it gets larger, relative to S.f.illigeri.

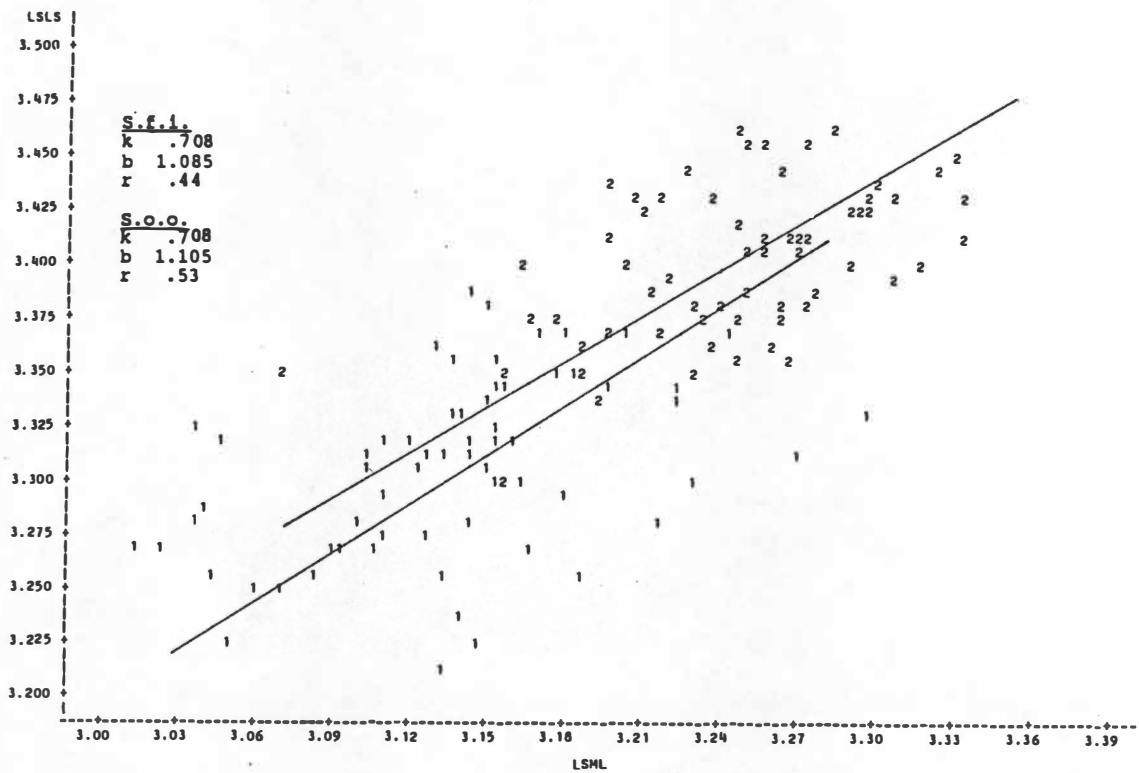


Figure 12. Reduced Major Axis regressions for the length of the spine of the scapula (LSLS) on the maximum length of the scapula (LSML).

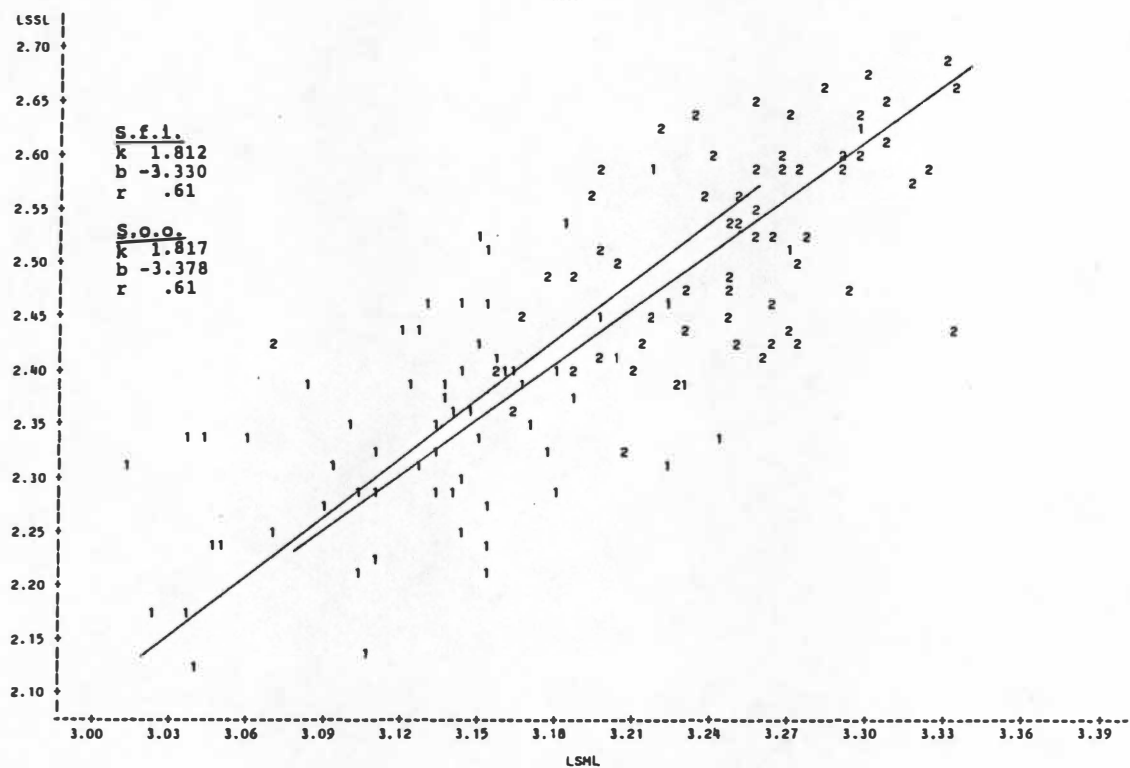


Figure 13. Reduced Major Axis regressions for the length of the supra-spinous line of the scapula (LSSL) on the maximum length of the scapula (LSML).

The reduced major axis slopes for the length of the infra-spinous line (LISL) of the scapula for S.o.oedipus and S.f.illigeri are 1.386 and 1.071, respectively. The 95% confidence interval indicates that the slope for S.f.i. is not significantly different from isometry (1.0), while the slope for S.o.o. is more positively allometric. The Z-statistic reveals that the intraspecific slopes are significantly different. A visual examination of the plots (Figure 14.) indicates that the regression lines for S.o.oedipus are a geometrically extended version of the variability found in S.f.illigeri, a case of hypermorphosis.

The reduced major axis slopes for the breadth of the glenoid cavity (LGCB) of the scapula for S.o.oedipus and S.f.illigeri are 1.199 and 0.884, respectively. The 95% confidence interval reveals that neither slope is significantly different from isometry (1.0). The Z-statistic reveals that neither slope is significantly different from each other. A qualitative examination of the plots (Figure 15.) indicate that the regression lines for S.o.oedipus are pre-displaced above those for S.f.illigeri. The pre-displacement retains the function of the glenoid cavity of S.o.o. relative to S.f.i.. The pre-displacement of the glenoid cavity is a requisite to retain the function, specifically the rotation of the humerus head relative to the glenoid cavity.

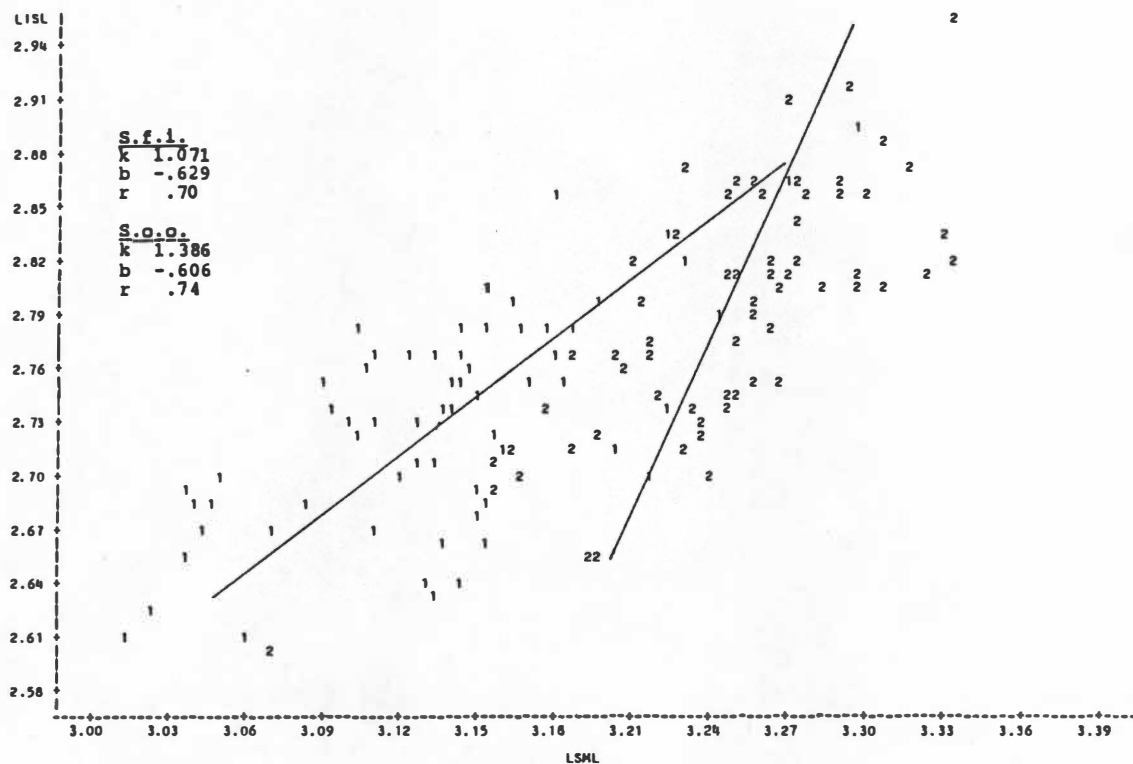


Figure 14. Reduced Major Axis regressions for the length of the infra-spinous line of the scapula (LISL) on the maximum length of the scapula (LSML).

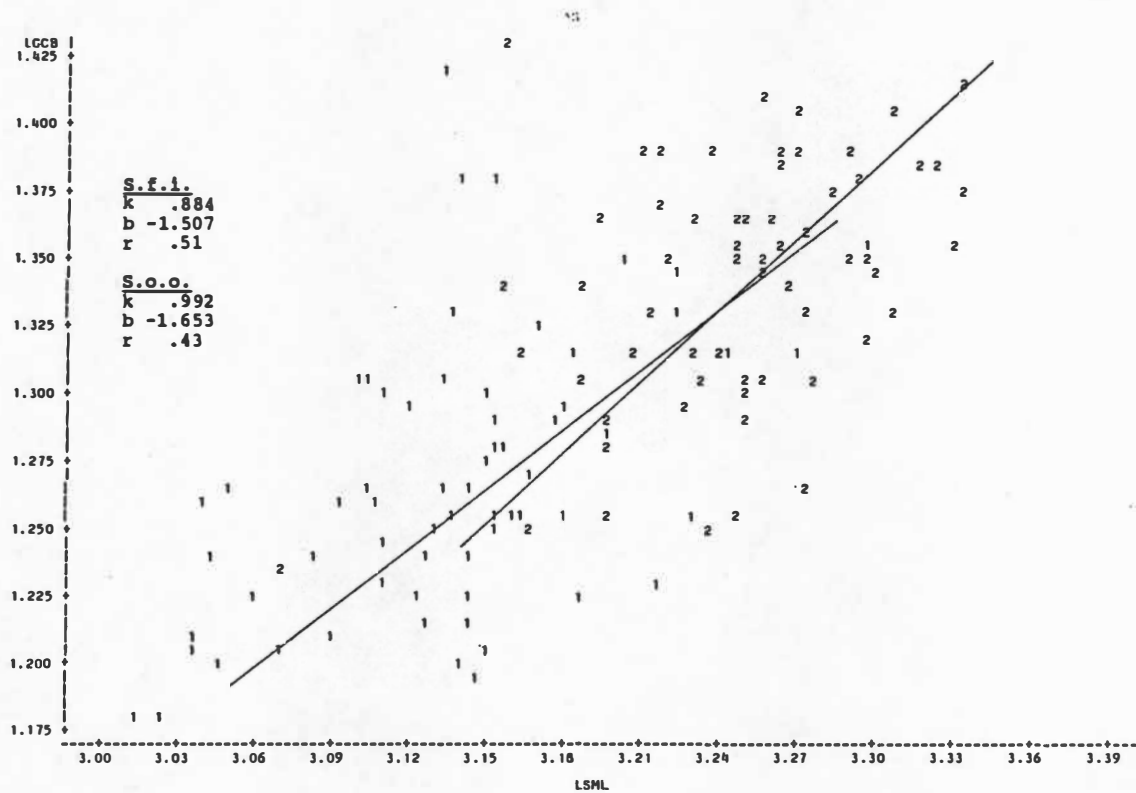


Figure 15. Reduced Major Axis regressions for the glenoid cavity breadth of the scapula (LGCB) on the maximum length of the scapula (LSML).

The reduced major axis slopes for the mid-glenoid to inferior angle length (LGIL) of the scapula for S.o.oedipus and S.f.illigeri are 0.742 and 0.958, respectively. the 95% confidence interval reveals that the slope for S.f.i. is significantly different from isometry (1.0), while the slope for S.o.o. is more negatively allometric. The Z-statistic indicates that the slopes for S.o.oedipus and S.f.illigeri are significantly different from each other. A visual examination of the plots (Figure 16.), coupled with a significant Z-score, indicates that a case for post-displacement may be made. Post-displacement describes a transposition of slopes, and intercepts. This transposition acts to retain the functional equivalence of the structure in the larger animal relative to that of the smaller.

The reduced major axis slopes for the trochanteric length (LFTL) of the femur for S.o.oedipus and S.f.illigeri are 0.982 and 0.998, respectively. The 95% confidence interval indicates that the slopes for the two groups are not significantly different from isometry (1.0). The Z-statistic reveals that slopes are not significantly different from each other. A visual examination of the plots (Figure 17.) indicate that the regression lines for S.o.oedipus are representative of an extension of the variability viewed in S.f.illigeri. S.o.oedipus, in this case, is comparable to an "overgrown" S.f.illigeri.

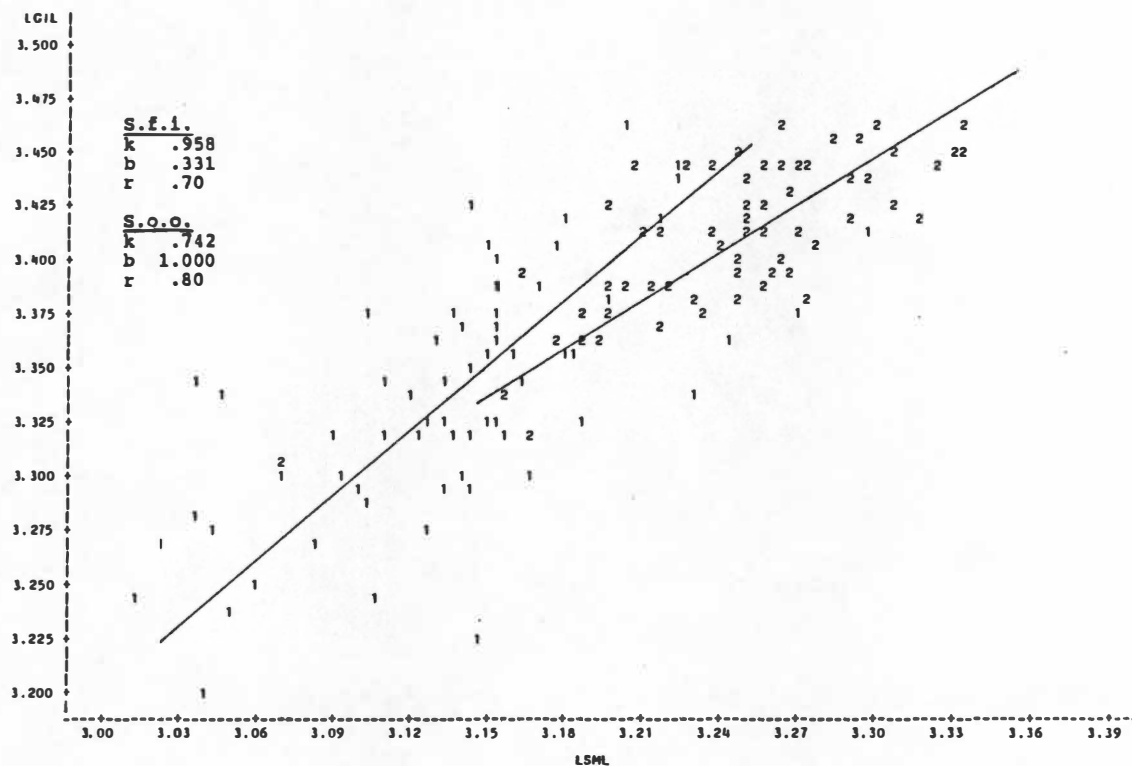


Figure 16. Reduced Major Axis regressions for the mid glenoid to inferior angle length of the scapula (LGIL) on the maximum length of the scapula (LSML).

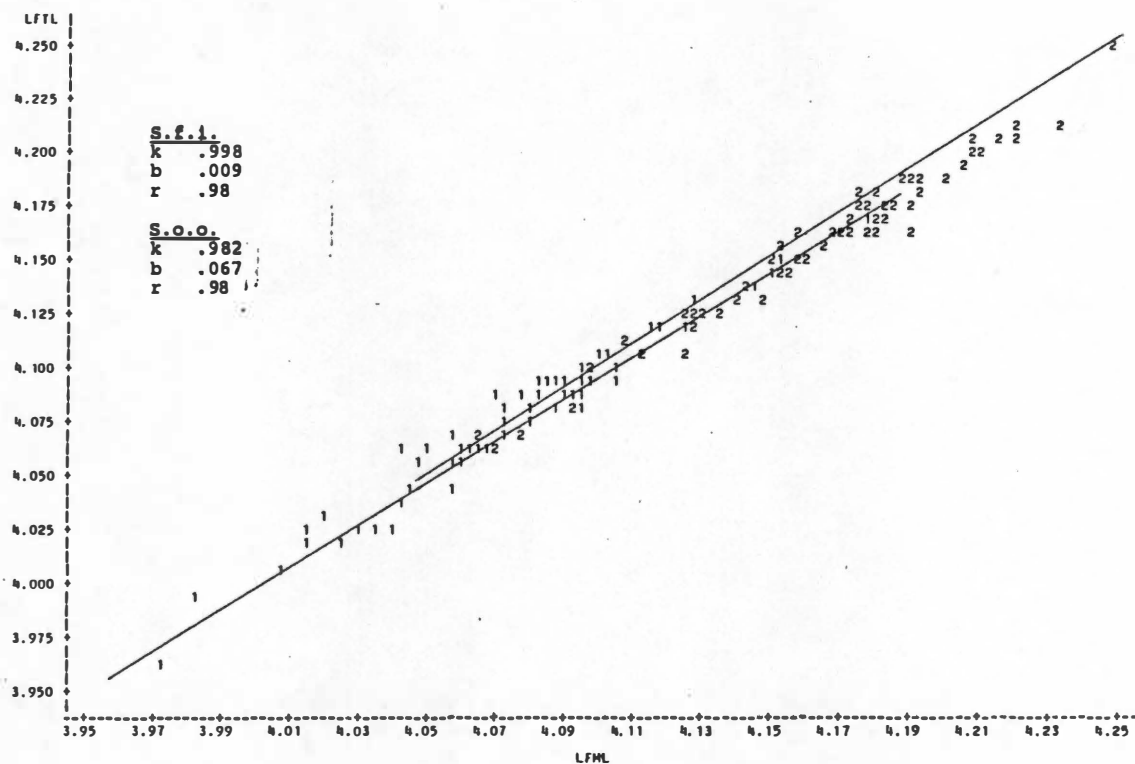


Figure 17. Reduced Major Axis regressions for the trochanteric length of the femur (LFTL) on the maximum length of the femur (LFML).

Morphologically it appears that as the femur increases in size, so does the trochanteric length.

The reduced major axis slopes for the vertical diameter (LVHD) of the femur head for S.o.oedipus and S.f.illigeri are 1.114 and 0.898, respectively. The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic suggests that the slopes are not significantly different from each other. A qualitative examination of the plots (Figure 18.) indicates that the S.o.oedipus regression lines are merely an extension of the variability exhibited by those representing S.f.illigeri. In this case, the slope for S.o.oedipus appears to be significantly steeper than the slope for S.f.illigeri, indicating a case of hypermorphosis. The reduced major axis slopes for the breadth of the epicondyles (LFEB) of the femur for S.o.oedipus and S.f.illigeri are 0.931 and 0.947, respectively. The 95% confidence interval indicates that the slopes for the two species are not significantly different from isometry (1.0). The Z-statistic reveals that neither of the slopes are significantly different from each other. A visual examination of the plots (Figure 19.) indicates that the regression lines of S.o.oedipus are a hypermorphic extension of the variability viewed in S.f.illigeri.

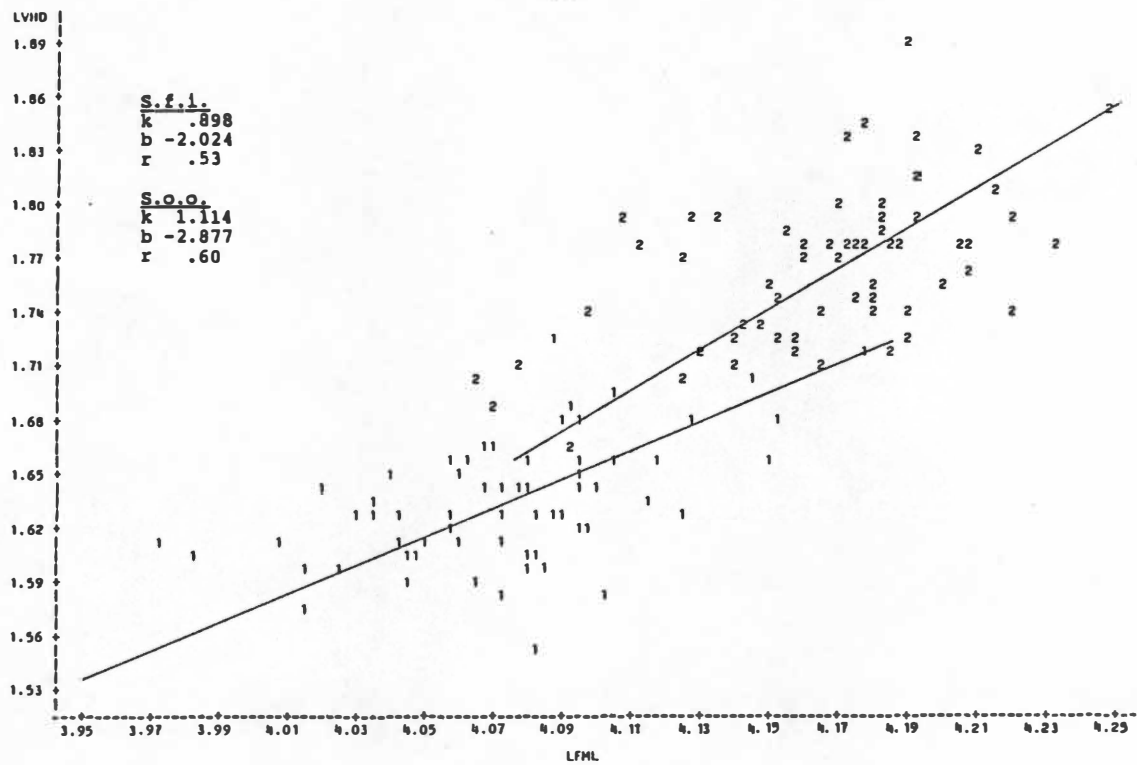


Figure 18. Reduced Major Axis regressions for the vertical diameter of the head of the femur (LVHD) on the maximum length of the femur (LFML).

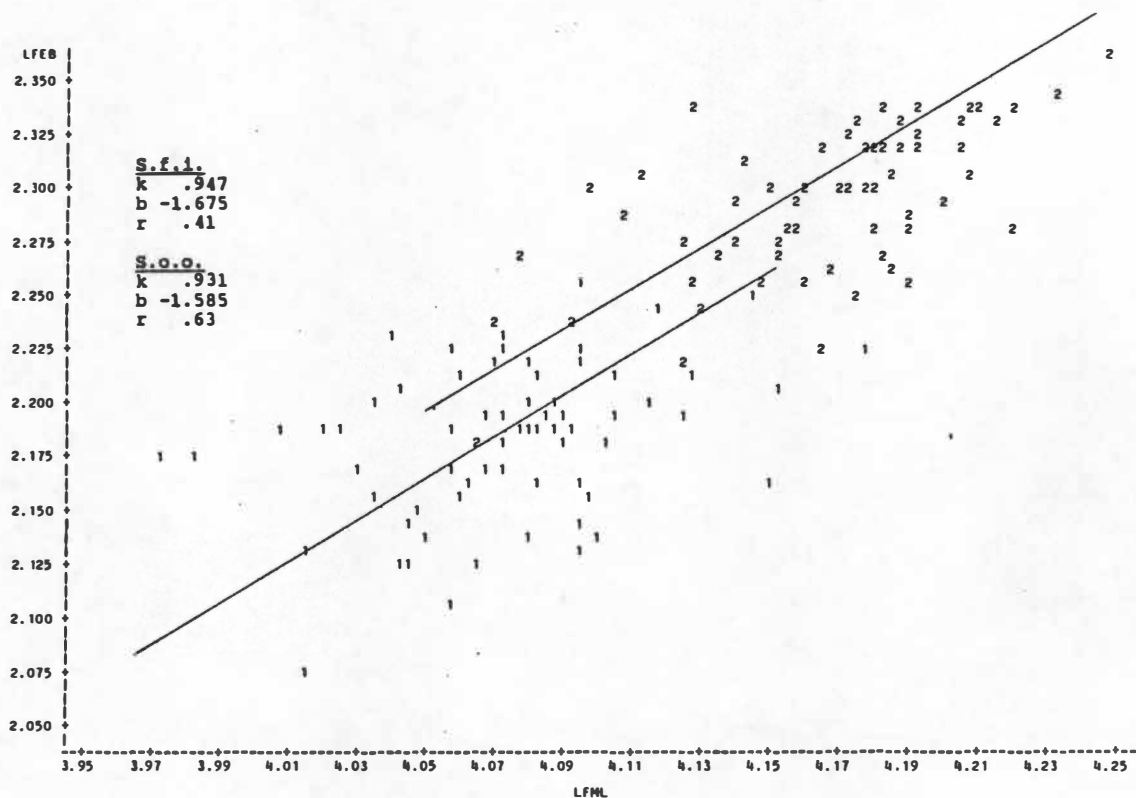


Figure 19. Reduced Major Axis regressions for the epicondylar breadth of the femur (LFEB) on the maximum length of the femur (LFML).

The reduced major axis slopes for the anterior-posterior diameter of the midshaft (LAPS) of the femur for S.o.oedipus and S.f.illigeri are 1.446 and 1.569, respectively. The 95% confidence interval indicates that both slopes are significantly different from isometry (1.0). The Z-statistic reveals that the slopes for S.f.illigeri and S.o.oedipus are not significantly different from each other. Examination of the plots (Figure 20.), indicate that the regression lines for S.o.oedipus are post-displaced beneath those of S.f.illigeri.

The reduced major axis slopes for the anterior-posterior diameter of the lateral condyle (LAPL) of the femur for S.o.oedipus and S.f.illigeri are 1.034 and 1.157, respectively. The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic indicates that the slopes for the two groups are not significantly different from each other. A qualitative examination of the plots (Figure 21.) reveal that the regression lines for S.o.oedipus are an extension of the variability present in the lines of S.f.illigeri. In this case, hypermorphosis, noted due to the extension of the slope for S.o.oedipus relative to S.f.illigeri, may be related to functional equivalence or adaptive changes involved in the functional structure of the condyle.

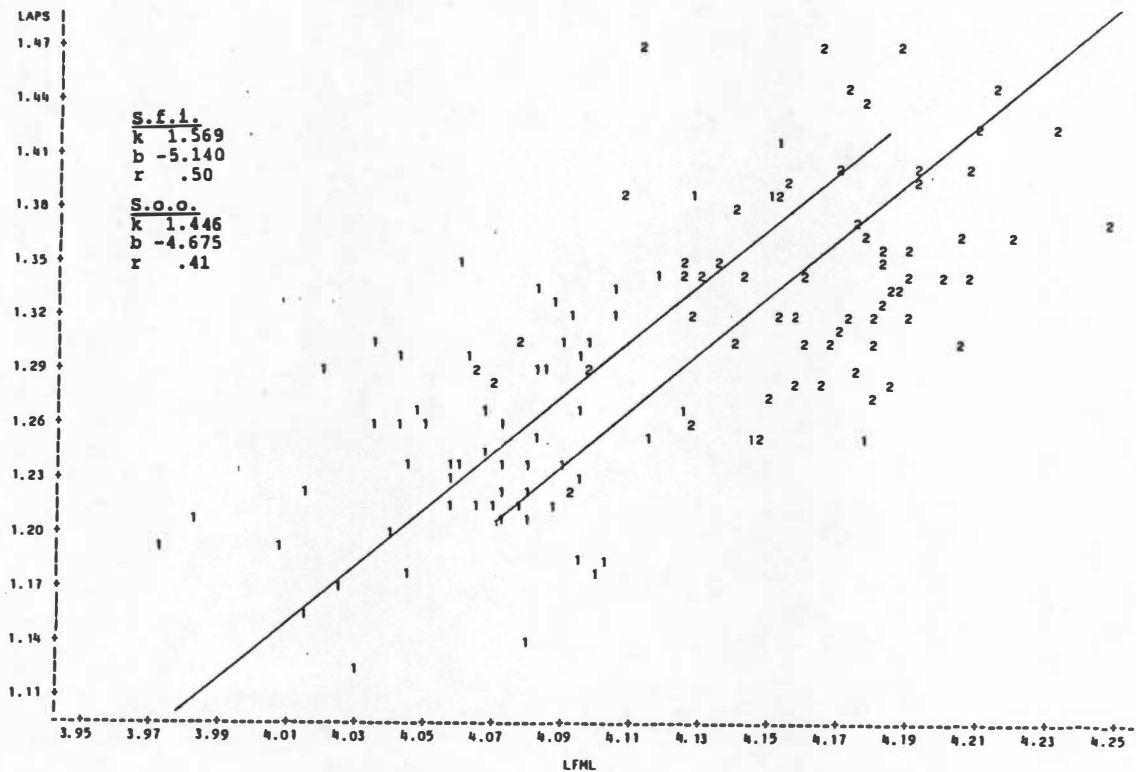


Figure 20. Reduced Major Axis regressions for the anterior-posterior diameter of the midshaft of the femur (LAPS) on the maximum length of the femur (LFML).

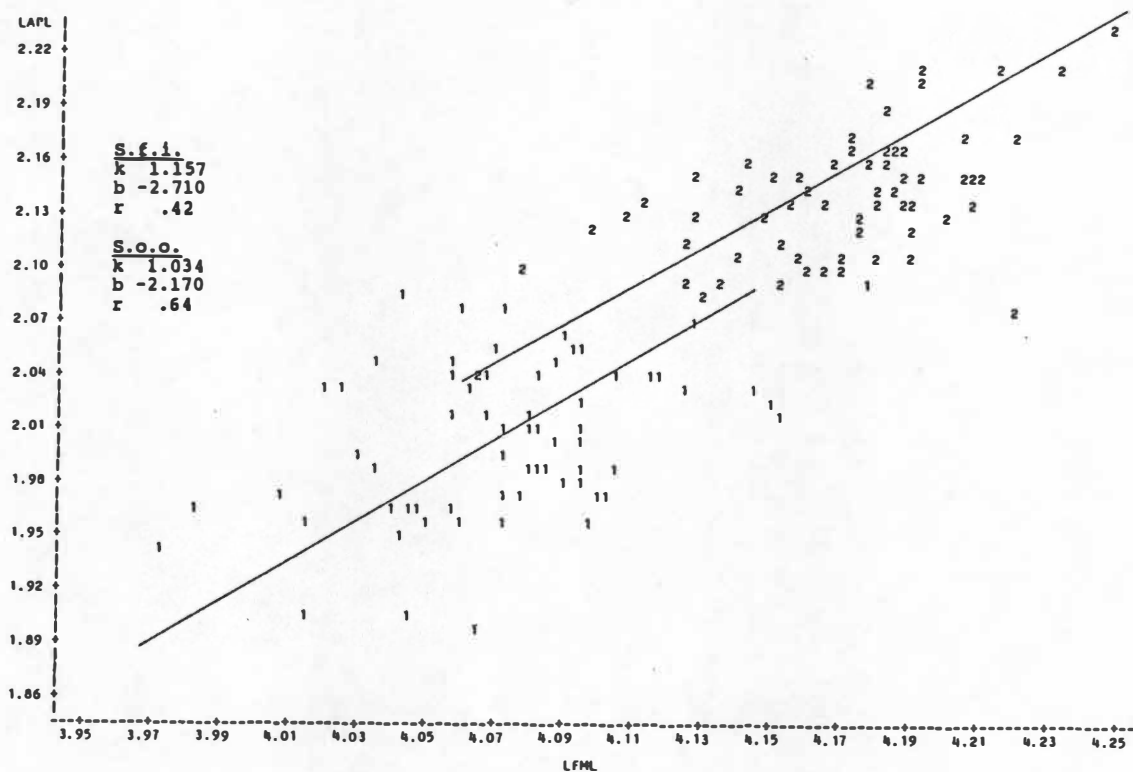


Figure 21. Reduced Major Axis regressions for the anterior-posterior diameter of the lateral condyle of the femur (LAPL) on the maximum length of the femur (LFML).

The reduced major axis slopes for the anterior-posterior diameter of the medial condyle (LAPM) of the femur for S.o.oedipus and S.f.illigeri are 1.062 and 0.950, respectively. The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic reveals the slopes are not significantly different from each other. A visual examination of the plots (Figure 22.) indicates that the regression lines for S.o.oedipus are an extension of the variability of the viewed in S.f.illigeri. Rather, the term hypermorphosis best describes the size and shape scaling patterning indicated by the plots.

The reduced major axis slopes for the anterior-posterior diameter at the nutrient foramen (LAPN) of the tibia for S.o.oedipus and S.f.illigeri are 1.879 and 1.784, respectively. The 95% confidence interval indicates that the slopes are significantly different. The Z-statistic reveals that the slopes for the two groups are not significantly different from each other. The visual examination of the plots (Figure 23.) revealed that the regression lines for S.o.oedipus were an extension of the variability of the variation in S.f.illigeri. In this case, S.o.oedipus is an "overgrown" S.f.illigeri.

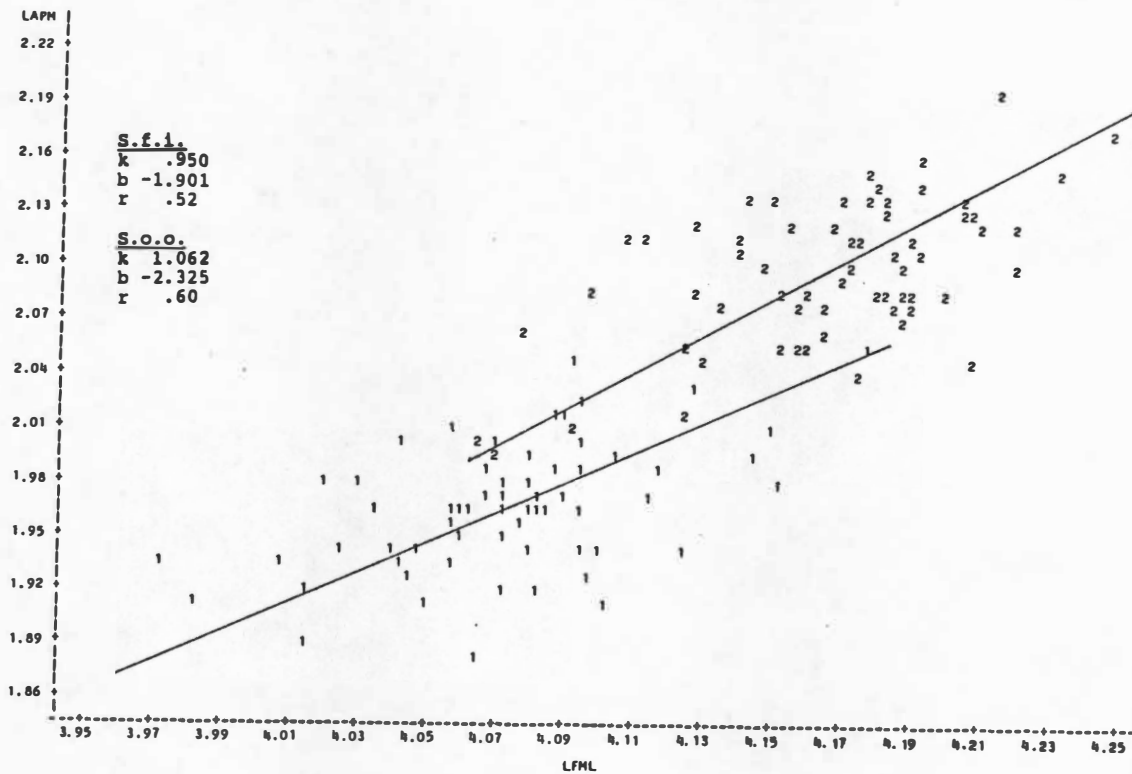


Figure 22. Reduced Major Axis regressions for the anterior-posterior diameter of the medial condyle of the femur (LAPM) on the maximum length of the femur (LFML).

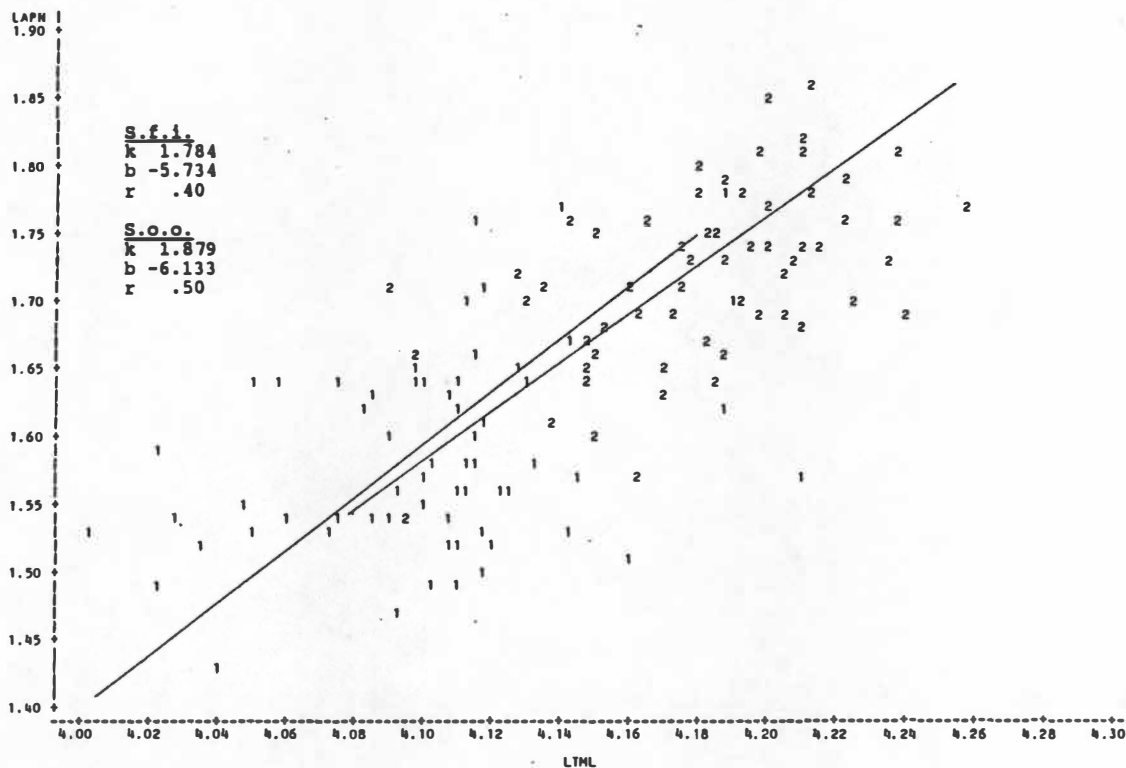


Figure 23. Reduced Major Axis regressions for the anterior-posterior diameter at the nutrient foramen of the tibia (LAPN) on the maximum length of the tibia (LTML).

The reduce major axis slopes for the medial-lateral diameter at the nutrient foramen (LMLM) of the tibia for S.o.oedipus and S.f.illigeri are 2.116 and 1.804, respectively. The 95% confidence interval indicates that the slopes are significantly different from isometry (1.0), positively allometric. The Z-statistic indicates that the slopes for the two species are not significantly different from each other. A qualitative examination of the plots (Figure 24.) reveals that the regression lines for S.o.oedipus are an extension of the variability of that viewed in S.f.illigeri. Hypermorphosis best describes the condition viewed in the two examples above. The larger species (S.o.oedipus) is best described as an "overgrown" S.f.illigeri.

The reduced major axis slopes for the position of the nutrient foramen (LCFL) of the tibia for S.o.oedipus and S.f.illigeri are 1.918 and 2.393, respectively. The 95% confidence interval indicates that the slopes for the two species are significantly different from isometry (1.0). The Z-statistic indicates that the slope values are not significantly different from each other. A qualitative examination of the plots (Figure 25.) reveals that the slopes for S.o.oedipus are post-displaced beneath those for S.f.illigeri.

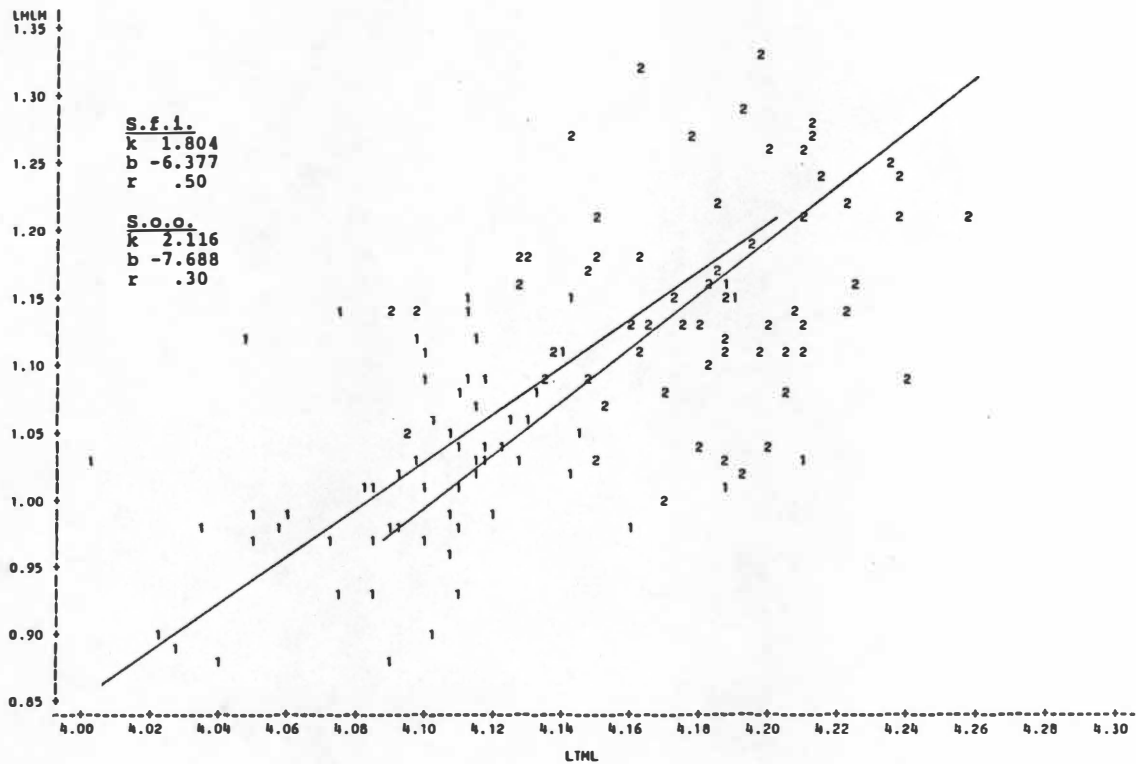


Figure 24. Reduced Major Axis regressions for the medial-lateral diameter at the nutrient foramen of the tibia (LMLM) on the maximum length of the tibia (LTML).

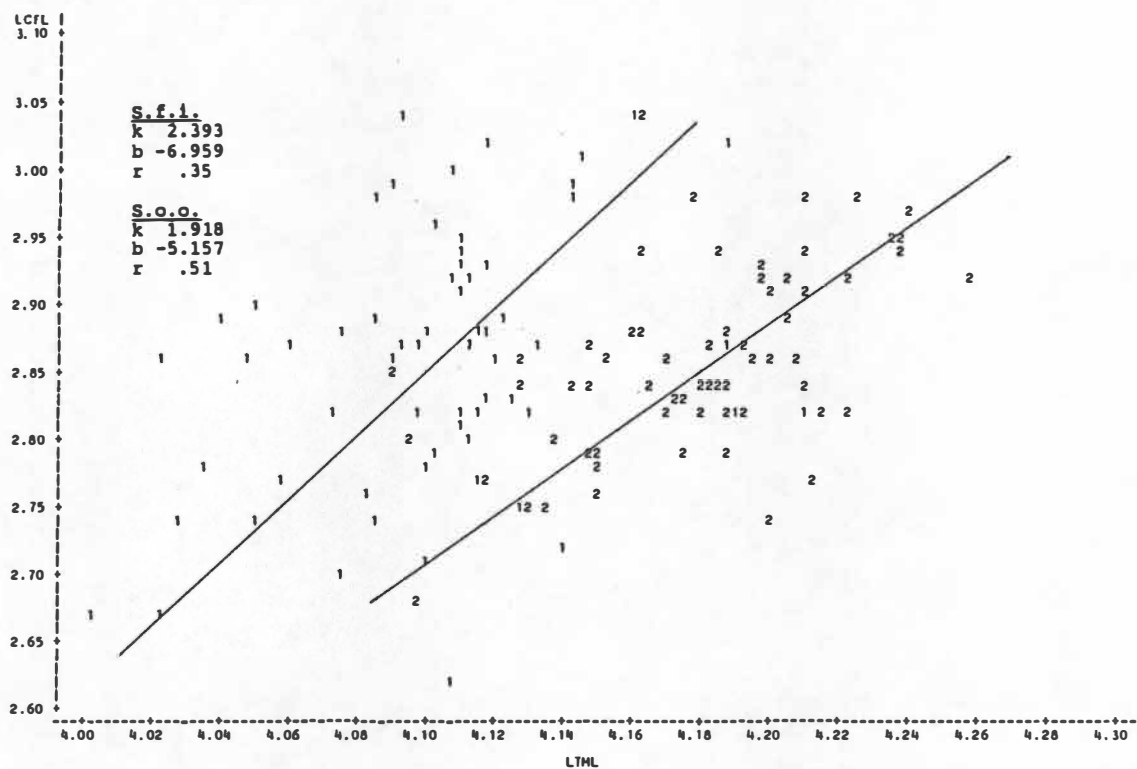


Figure 25. Reduced Major Axis regressions for the position of the nutrient foramen of the tibia (LCFL) on the maximum length of the tibia (LTML).

The reduced major axis slopes for the maximum breadth of the proximal epiphysis (LBPE) of the tibia for S.o.oedipus and S.f.illigeri are 0.897 and 0.809, respectively. The 95% confidence interval reveals that the slopes are not significantly different from isometry (1.0). The Z- statistic indicates that the slopes are not significantly different from each other. A visual examination of the plots (Figure 26.) indicates that the regression lines of S.o.oedipus are transposed above those for S.f.illigeri. This pre-displacement allows S.o.oedipus to retain its larger size without losing the functional equivalence of the breadth of the proximal epiphysis relative to S.f.illigeri.

The reduced major slopes for the maximum breadth of the distal epiphysis (LBDE) of the tibia for S.o.oedipus and S.f.illigeri are 1.062 and 1.059, respectively. The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z- statistic reveals that the slopes for the two species are not significantly different from each other. A qualitative examination of the plots (Figure 27.) indicate that the regression lines for S.o.oedipus are pre-displaced above those for S.f.illigeri. Positively a result of an attempt to retain the function of the structure regardless of an increase in size.

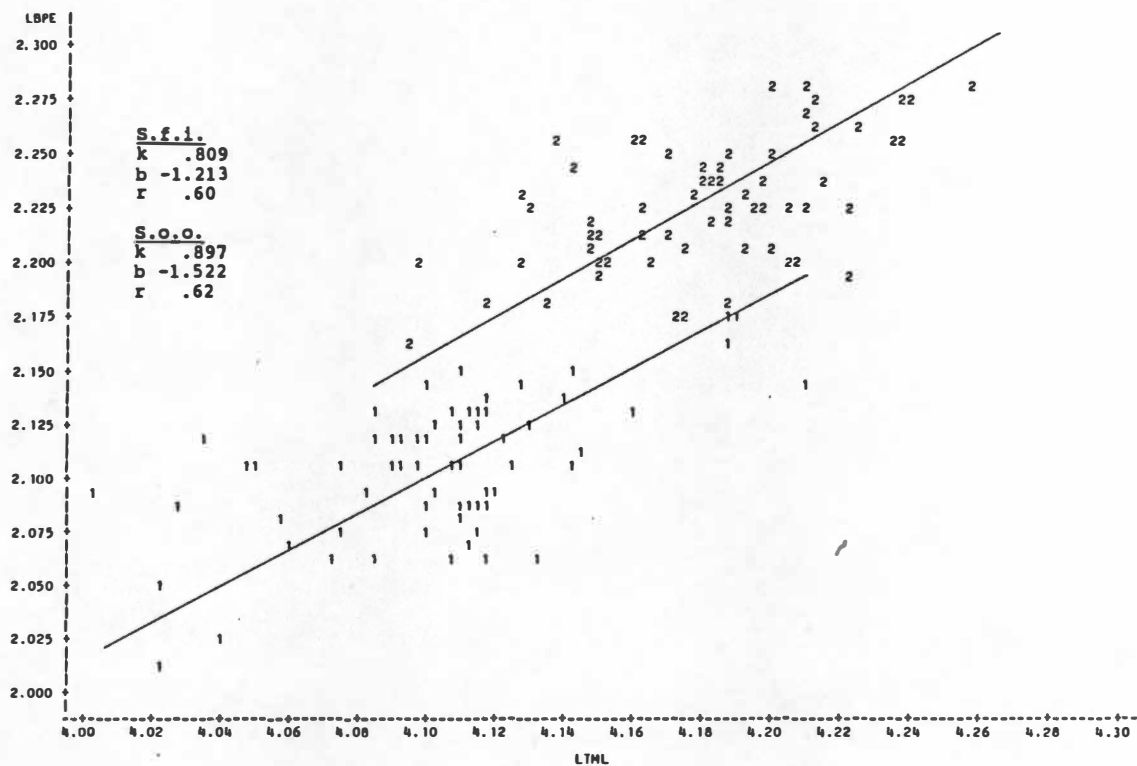


Figure 26. Reduced Major Axis regressions for the maximum breadth of the proximal epiphysis of the tibia (LBPE) on the maximum length of the tibia (LTML).

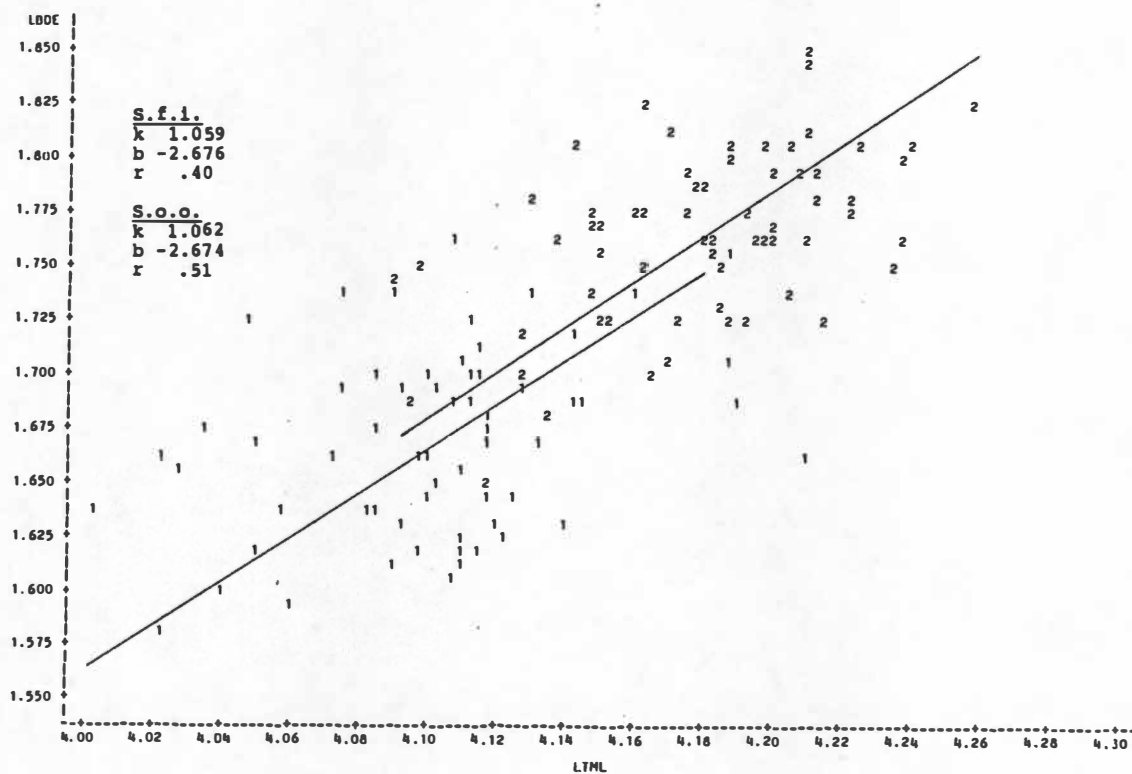


Figure 27. Reduced Major Axis regressions for the maximum breadth of the distal epiphysis of the tibia (LBDE) on the maximum length of the tibia (LTML).

The "bone by bone" approach was utilized to examine the overall morphological allometric variation found in the two species, however, it was deemed necessary to try and isolate areas of morphological importance. This was done in order to shed some light on possible patterning in the variability, as well as to provide some insight into possibly the functional aspects of the postcranial variation. In particular, the documented locomotor differences reported by Glassman (1983).

In order to isolate areas which might reflect locomotor and possibly positional behavioral related variation, a "limb" complex was created. The "limb" complex involves various long bone measurements of the upper and lower limbs regressed on the maximum length of the bone to which they share a functional relationship. The complex was created to elucidate patterns of morphological variation. Reduced major axis regression statistics were calculated for this complex, and interpreted according to the methods described in Chapter III. Table 9. presents the reduced major axis regression statistics for the "limb" complex. Correlations for the variable pairs are presented in Table 10.

The reduced major axis slopes for the humerus maximum length (LHML) regressed on scapula maximum length (LSML) for S.o.o. and S.f.i. are 0.747 and 0.592, respectively.

Table 9. Reduced Major Axis regression statistics for the "limb" complex. Slopes and intercepts are represented by k and b, respectively.

SPECIES	VAR1	k	Sek0	CI2	Z3	b
S.f.i.	LHML/LSML	0.592	0.064	0.463-0.720		2.002
S.o.o.	LHML/LSML	0.747	0.079	0.588-0.906	-1.860	1.494
S.f.i.	LHML/LSMB	0.746	0.068	0.628-0.900		1.446
S.o.o.	LHML/LSMB	1.014	0.094	0.826-1.203	-2.536*	0.633
S.f.i.	LHML/LRML	0.907	0.073	0.764-1.050		0.463
S.o.o.	LHML/LRML	1.040	0.081	0.879-1.202	-1.554	0.010
S.f.i.	LHML/LUML	0.996	0.074	0.848-1.144		-0.043
S.o.o.	LHML/LUML	1.103	0.072	0.958-1.248	-1.377	-0.456
S.f.i.	LUPL/LOCL	0.706	0.086	0.534-0.877		2.746
S.o.o.	LUPL/LOCL	0.527	0.060	0.406-0.648	2.637*	2.913
S.f.i.	LFML/LBML	0.960	0.059	0.843-1.078		0.182
S.o.o.	LFML/LBML	1.036	0.058	0.920-1.152	-1.230	-0.111
S.f.i.	LTML/LBML	1.011	0.022	0.966-1.056		0.008
S.o.o.	LTML/LBML	0.993	0.028	0.937-1.049	0.627	0.080

1. Variable definitions are found in Appendix C.
2. CI, Confidence Interval 95%
3. Z, Significance indicated by '*' (P > 0.05).

Table 10. Correlations for the variable pairs.

SPECIES	VAR1	r	P	SPECIES	VAR	r	P
S.f.i.	LHML/LSML	.50	.0001*2	S.f.i.	LHML/LUML	.81	.0001*
S.o.o.	LHML/LSML	.53	.0001*	S.o.o.	LHML/LUML	.90	.0001*
S.f.i.	LHML/LSMB	.71	.0001*	S.f.i.	LUPL/LOCL	.15	.2321
S.o.o.	LHML/LSMB	.70	.0001*	S.o.o.	LUPL/LOCL	.40	.0010
S.f.i.	LHML/LRML	.81	.0001*	S.f.i.	LFML/LBML	.91	.0001*
S.o.o.	LHML/LRML	.81	.0001*	S.o.o.	LFML/LBML	.90	.0001*
S.f.i.	LTML/LBML	.98	.0001*				
S.o.o.	LTML/LBML	.97	.0001*				

1. Variable definitions are found in Appendix C.
2. Values Significant are designated by '*'.

The 95% confidence interval indicates that the slopes for the two groups are significantly different from Isometry (1.0). The Z-statistic reveals that the slopes are not significantly different from each other. A visual examination of the plots (Figure 28.) indicates that the regression lines for S.o.oedipus are more steep than those presented for S.f.illigeri. In this case, the properties of hypermorphosis may be present.

The reduced major axis slopes for humerus maximum length (LHML) and scapula maximum breadth (LSMB) for S.o.oedipus and S.f.illigeri are 1.014 and 0.767, respectively. The 95% confidence interval indicates that the slope for S.f.i. is significantly different from isometry (1.0). The Z-statistic reveals that the slopes are significantly different from each other. A qualitative examination of the plots (Figure 29.) indicates that the regression lines for S.o.oedipus are steeper (more positively allometric) than those exhibited by S.f.illigeri. Hypermorphosis here could be postulated as an overall increase in the size of S.o.oedipus relative to S.f.illigeri.

The reduced major axis slopes for the maximum length of the humerus (LHML) and radius maximum length (LRML) for S.o.oedipus and S.f.illigeri are 1.040 and 0.907, respectively. The 95% confidence interval indicates that neither

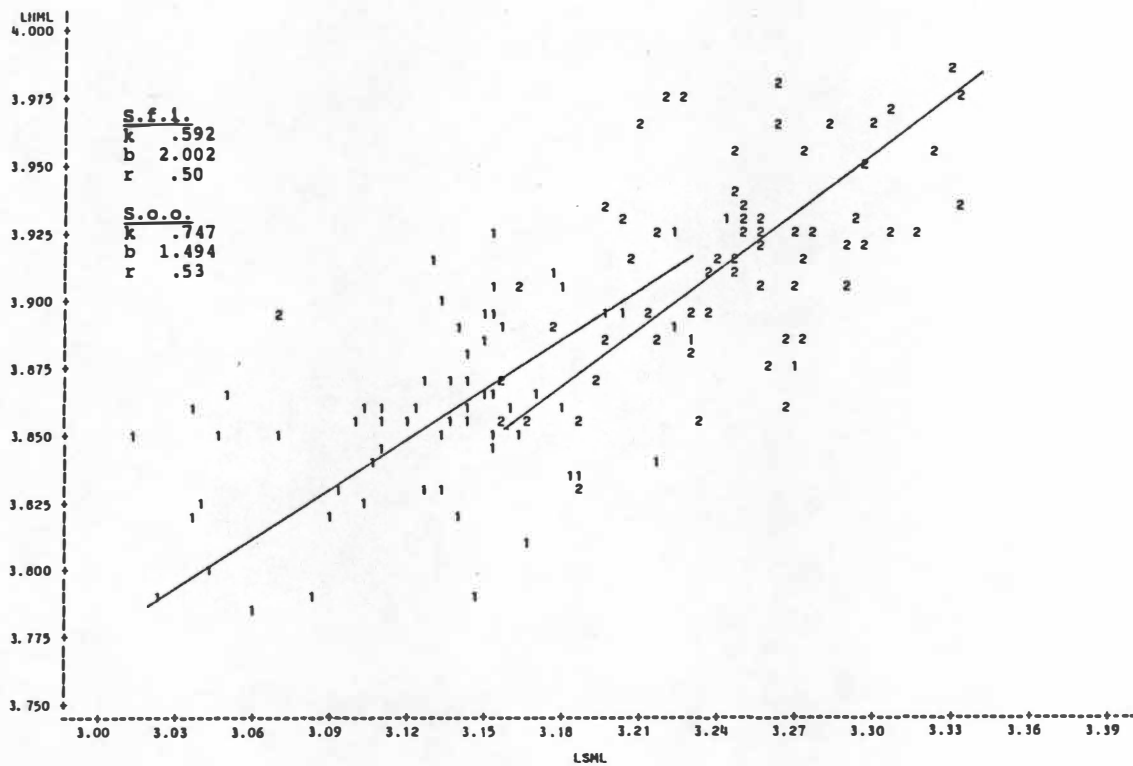


Figure 28. Reduced Major Axis regressions for the maximum length of the humerus (LHML) on the maximum length of the scapula (LSML).

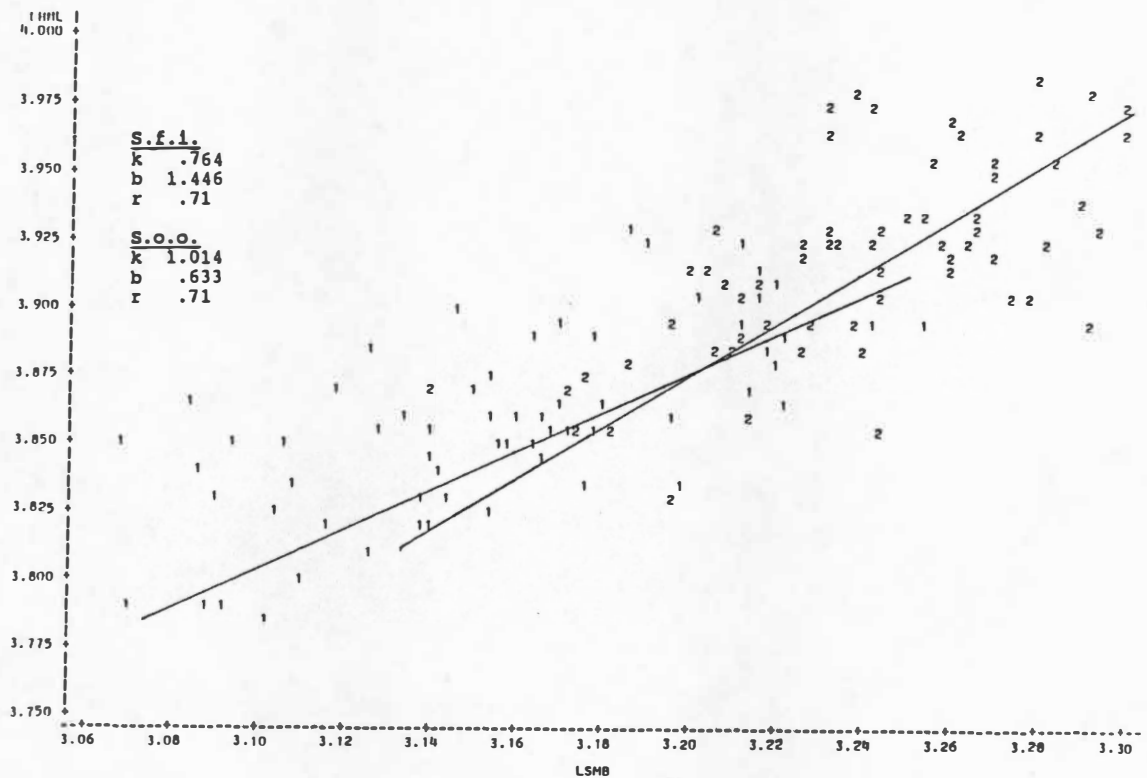


Figure 29. Reduced Major Axis regressions for the maximum length of the humerus (LHML) on the maximum breadth of the scapula (LSMB).

slope is significantly different from isometry. The Z-statistic indicates that the slopes are not significantly different from each other. A qualitative examination of the plots (Figure 30.) reveal that the regression lines for S.o.oedipus are pre-displaced above those for S.f.illigeri.

The reduced major axis slopes for the maximum length of the humerus (LHML) and the maximum length of the ulna (LUML) for S.o.oedipus and S.f.illigeri are 1.103 and 0.996, respectively. The confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic indicates that the slopes are not significantly different from each other. A visual examination of the plots (Figure 31.) indicates that the regression lines for S.o.oedipus represent an extension of the lines for S.f.illigeri. Rather, that as the ulna increases in size so does the humerus. This assessment seems logical, however, ontogenetic data would lend the ultimate support.

The reduced major axis slopes for the physiological length of the ulna (LUPL) and the olecranon process to coronoid process length (LOCL) for S.o.oedipus and S.f.illigeri are 0.527 and 0.706. The 95% confidence interval indicates that the slopes for the two species are significantly different from isometry (1.0).

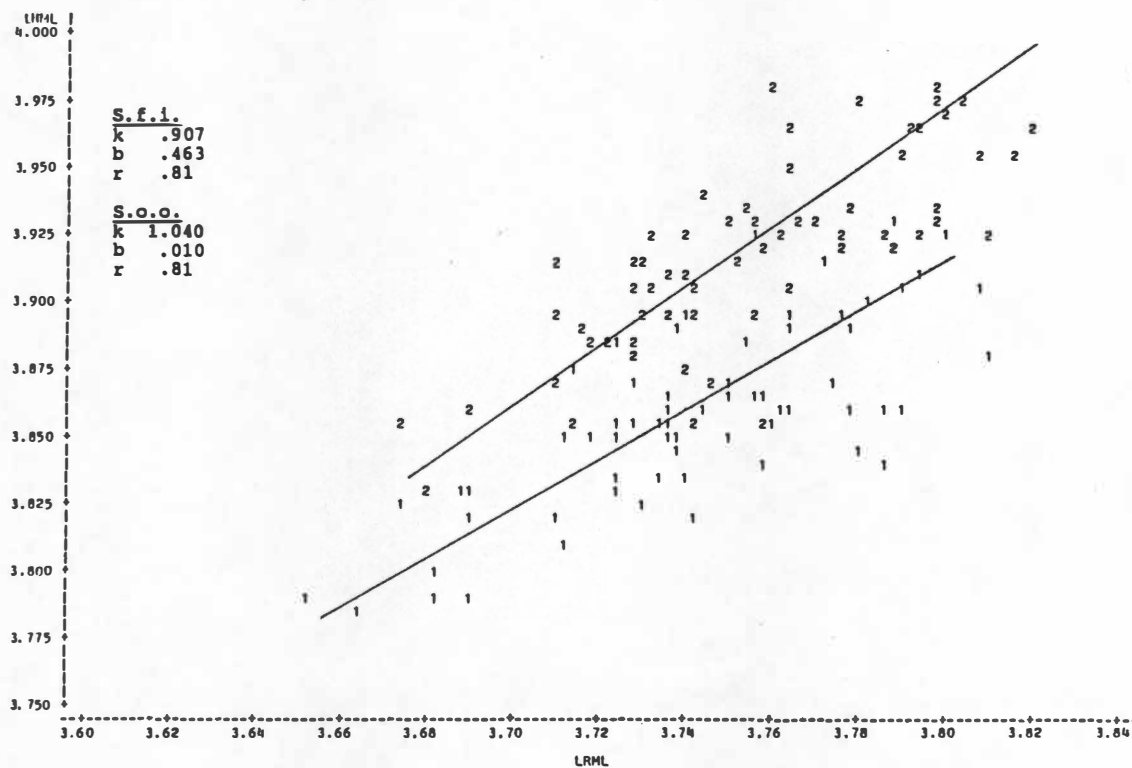


Figure 30. Reduced Major Axis regressions for the maximum length of the humerus (LHML) on the maximum length of the radius (LRML).

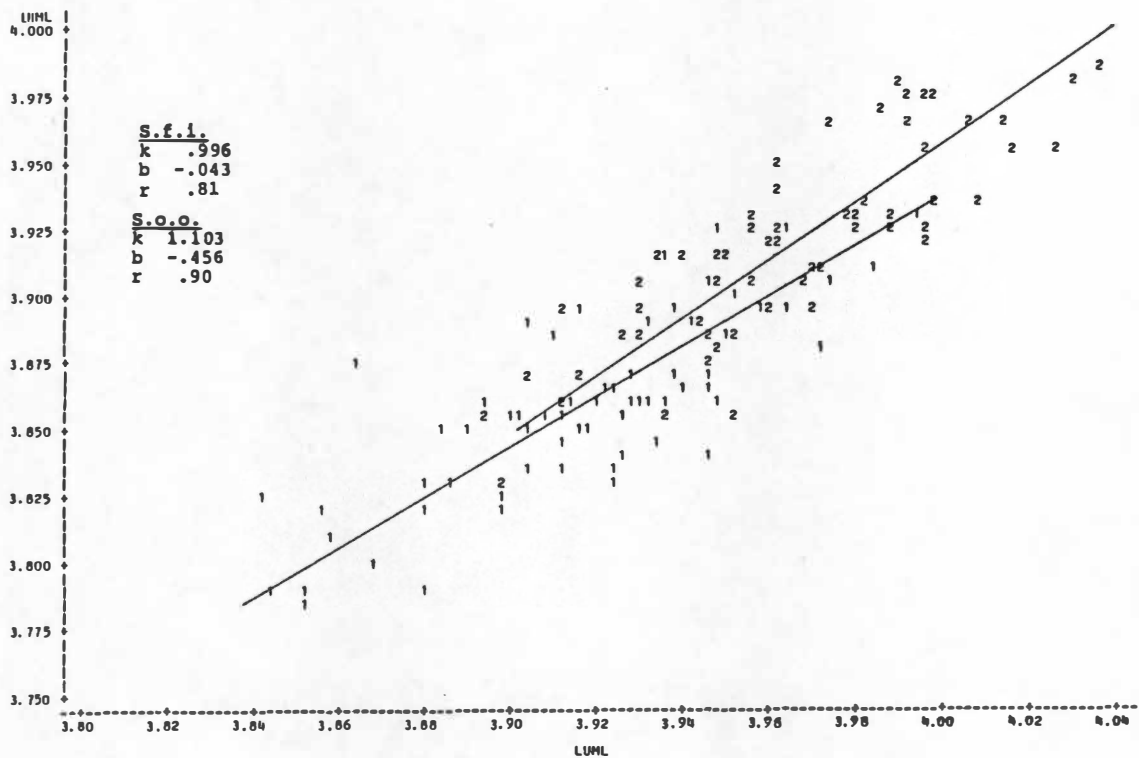


Figure 31. Reduced Major Axis regressions for the maximum length of the humerus (LHML) on the maximum length of the ulna (LUML)

The Z-statistic indicates that slopes are significantly different from each other. A qualitative examination of the plots (Figure 32.) indicates that the regression lines for S.o.oedipus may be post-displaced beneath those for S.f.i. It may be, because the slopes are negative, that the olecranon process is taking on a new function, rather than preserving the old, thus lending support to Glassman's (1983) contentions for the generation of greater propulsion by S.o.oedipus relative to S.f.illigeri.

The reduced major axis slopes for the maximum length of the femur (LFML) and the maximum length of the fibula (LBML) are 1.036 and 0.960, respectively. The 95% confidence interval indicates that the slopes for the two species are not significantly different from isometry (1.0). A visual examination of the plots (Figure 33.) indicates that the regression lines for S.o.oedipus are an extension of those exhibited by S.f.illigeri. Rather the relationship between maximum length of the femur and fibula maximum length is hypermorphic.

The reduced major axis slopes for the tibia maximum length (LTML) and the length of the fibula (LBML) are 0.993 and 1.011, respectively. The 95% confidence interval reveals that the slopes are not significantly different from isometry. The Z-statistic indicates that the slopes are not significantly different from each other.

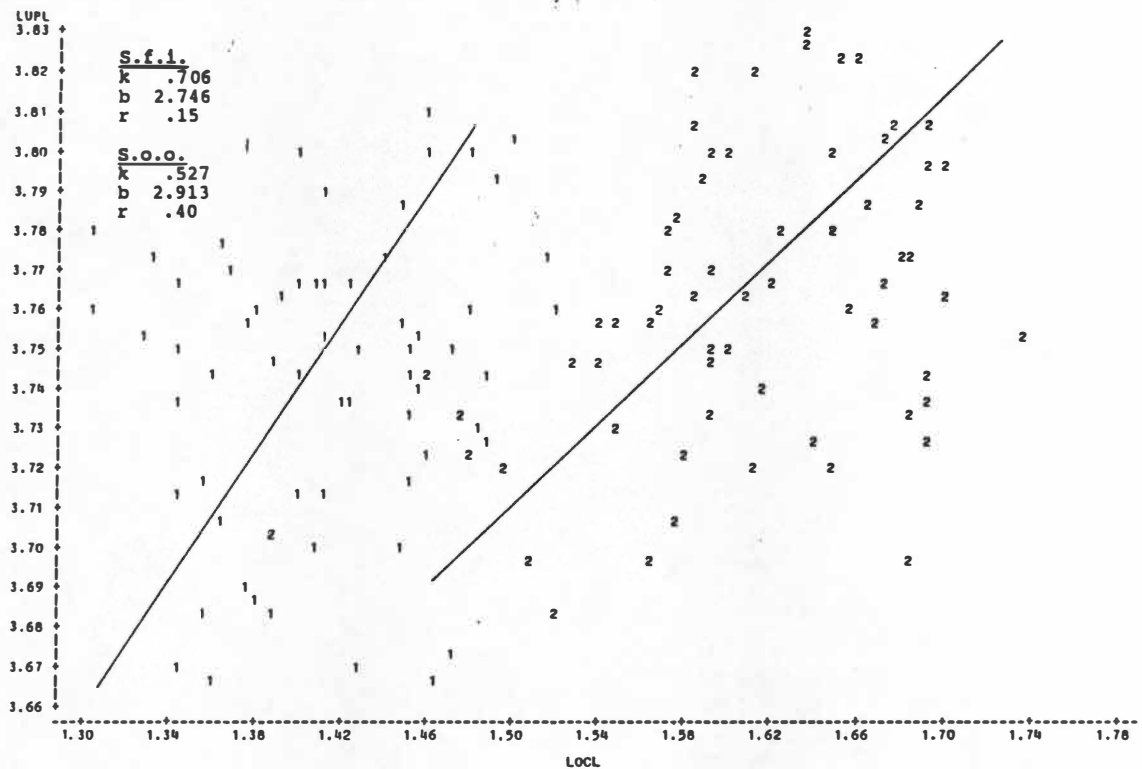


Figure 32. Reduced Major Axis regressions for the physiological length of the ulna (LUPL) on the olecranon process to coronoid process length of the ulna (LOCL).

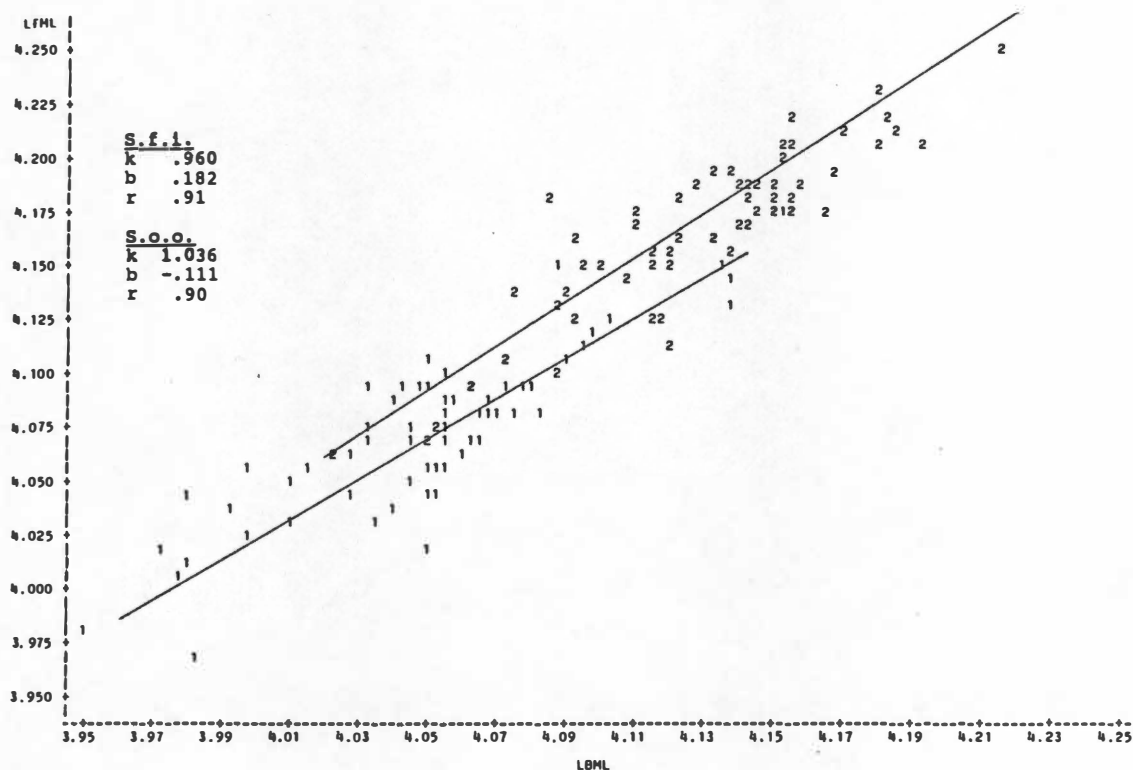


Figure 33. Reduced Major Axis regressions for the maximum length of the femur (LFML) on the maximum length of the fibula (LBML).

A qualitative examination of the plots (Figure 34.) indicates that the regression lines for S.o.oedipus are an extension of the variability exhibited by S.f.illigeri.

In order to make generalized statements concerning size and shape variation between the two species, all major long bone measurements were regressed on femur maximum length. In this case, femur maximum length is being used as a general measure of body size. The femur maximum length is being used because measures of body weight for the tamarins included in this analysis are difficult to obtain, and difficult to verify. This study does not assume that femur maximum length is a true measure of body size, but rather an acceptable one in light of the tenuous nature of the recording of body weight at the Oak Ridge Marmoset Research Center.

Results of the reduced major axis slopes and intercepts were interpreted in the fashion as the in the previous analyses. A brief description of the method of qualitative interpretation is presented in Chapter IV. The null hypothesis is, as previously, stated, if the slopes are not significantly different (at 0.05) , then the bivariate plots would be interpreted qualitatively.

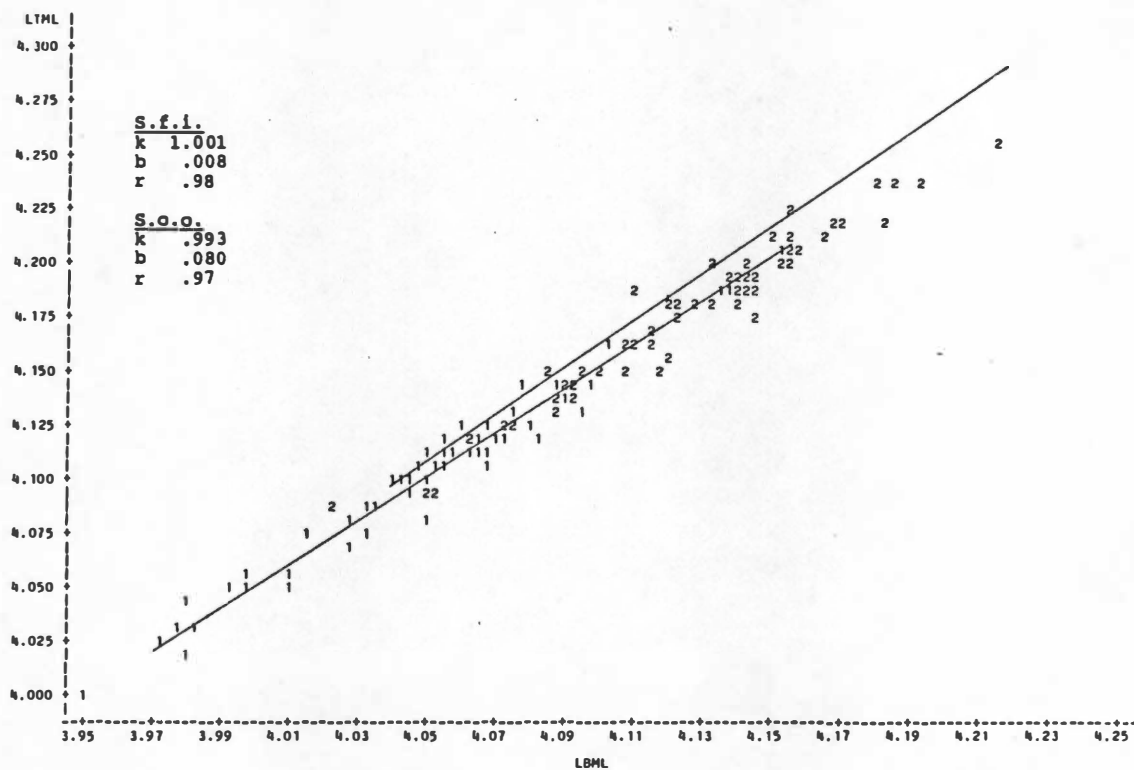


Figure 34. Reduced Major Axis regressions for the maximum length of the tibia (LTML) on the maximum length of the fibula (LBML).

The reduced major axis statistics for the maximum length of all major limb bones on femur maximum length (LFML), and correlations for the variable pairs are found in Tables 11. and 12.

The reduced major axis slopes for the maximum length of the humerus (LHML) for S.o.oedipus and S.f.illigeri are 0.965 and 0.897, respectively. The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic reveals that the slopes for the two speies are not significantly different from each other. A visual examination of the plots (Figure 35.) indicates that the regression lines for S.o.oedipus are post-displaced beneath those for S.f.illigeri. In this case, function does not change as the size of the animals increase.

The reduced major axis slopes for the maximum length of the radius (LRML) for S.o.oedipus and S.f.illigeri are 0.928 and 0.965, respectively. The 95% confidence interval indicates that the slopes for the two groups are not significantly different from isometry (1.0). The Z-statistic reveals that the slopes are not significantly different from each other. A visual examination of the plots (Figure 36.) indicates that the regression lines for S.o.oedipus are post-displaced beneath those for S.f.illigeri.

Table 11. Reduced Major Axis regression statistics for the maximum length of all major limb bones on femur maximum length (LFML). Slopes and intercepts are represented by k and b, respectively.

SPECIES	VAR1	k	Sek0	CI2	Z3	b
S.f.i.	LHML/LFML	0.897	0.069	0.758-1.035		0.206
S.o.o.	LHML/LFML	0.965	0.065	0.836-1.097	-0.987	-0.104
S.f.i.	LRML/LFML	0.989	0.076	0.836-1.141		-0.283
S.o.o.	LRML/LFML	0.928	0.078	0.771-1.085	0.721	-0.109
S.f.i.	LTML/LFML	1.052	0.064	0.925-1.180		-0.184
S.o.o.	LTML/LFML	0.958	0.050	0.859-1.058	1.750	0.187
S.f.i.	LUML/LFML	0.900	0.073	0.755-1.045		0.249
S.o.o.	LUML/LFML	0.875	0.059	0.758-0.922	0.395	0.319
S.f.i.	LUPL/LFML	0.993	0.087	0.818-1.168		-0.302
S.o.o.	LUPL/LFML	0.954	0.075	0.804-1.105	0.466	-0.215
S.f.i.	LSML/LFML	1.516	0.158	1.200-1.832		-3.037
S.o.o.	LSML/LFML	1.293	0.138	1.016-1.569	1.365	-2.140

1. Variable definitions are found in Appendix C.
2. CI, Confidence Interval 95%.
3. Z, Significance indicated by '*' (P > 0.05).

Table 12. Correlations for the variable pairs.

SPECIES	VAR1	r	P	SPECIES	VAR	r	P
S.f.i.	LHML/LFML	.81	.0001*2	S.f.i.	LUPL/LFML	.71	.0001*
S.o.o.	LHML/LFML	.84	.0001*	S.o.o.	LUPL/LFML	.78	.0001*
S.f.i.	LRML/LFML	.81	.0001*	S.f.i.	LSML/LFML	.53	.0001*
S.o.o.	LRML/LFML	.74	.0001*	S.o.o.	LSML/LFML	.52	.0001*
S.f.i.	LUML/LFML	.76	.0001*	S.f.i.	LTML/LFML	.90	.0001*
S.o.o.	LUML/LFML	.84	.0001*	S.o.o.	LTML/LFML	.91	.0001*

1. Variable definitions are found in Appendix C.
2. Values significant are indicated by '*'.

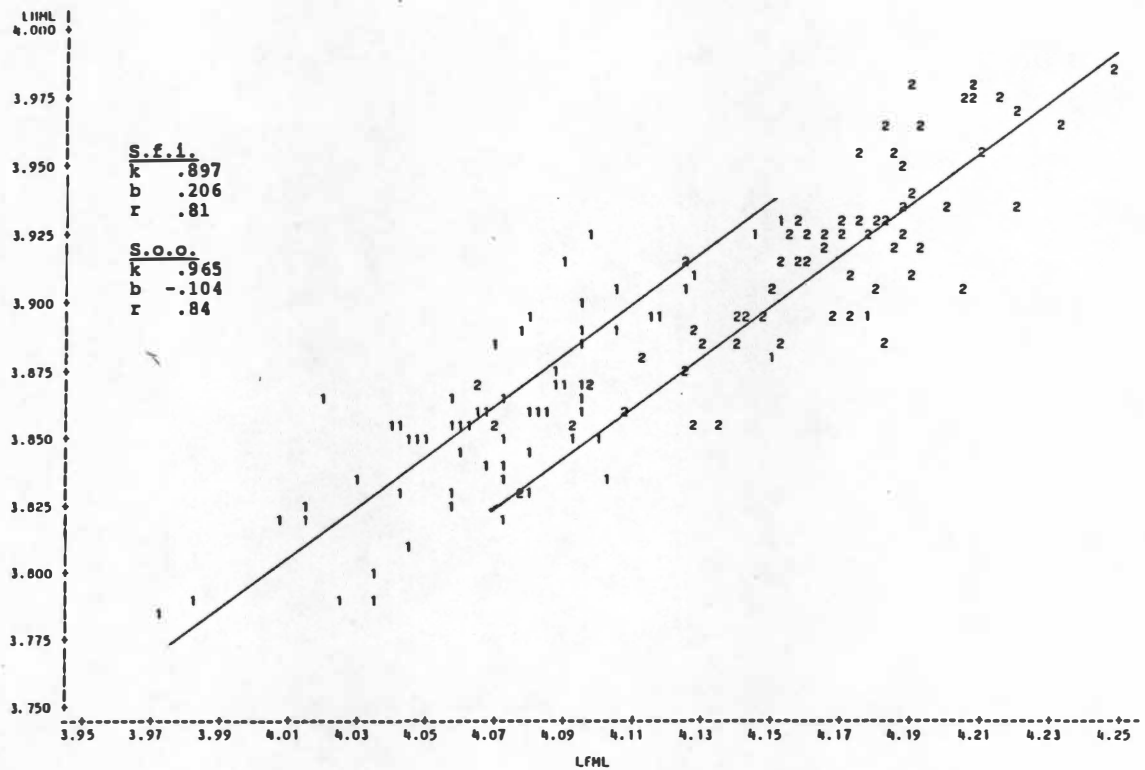


Figure 35. Reduced Major Axis regressions for the maximum length of the humerus (LHML) on the maximum length of the femur (LFML).

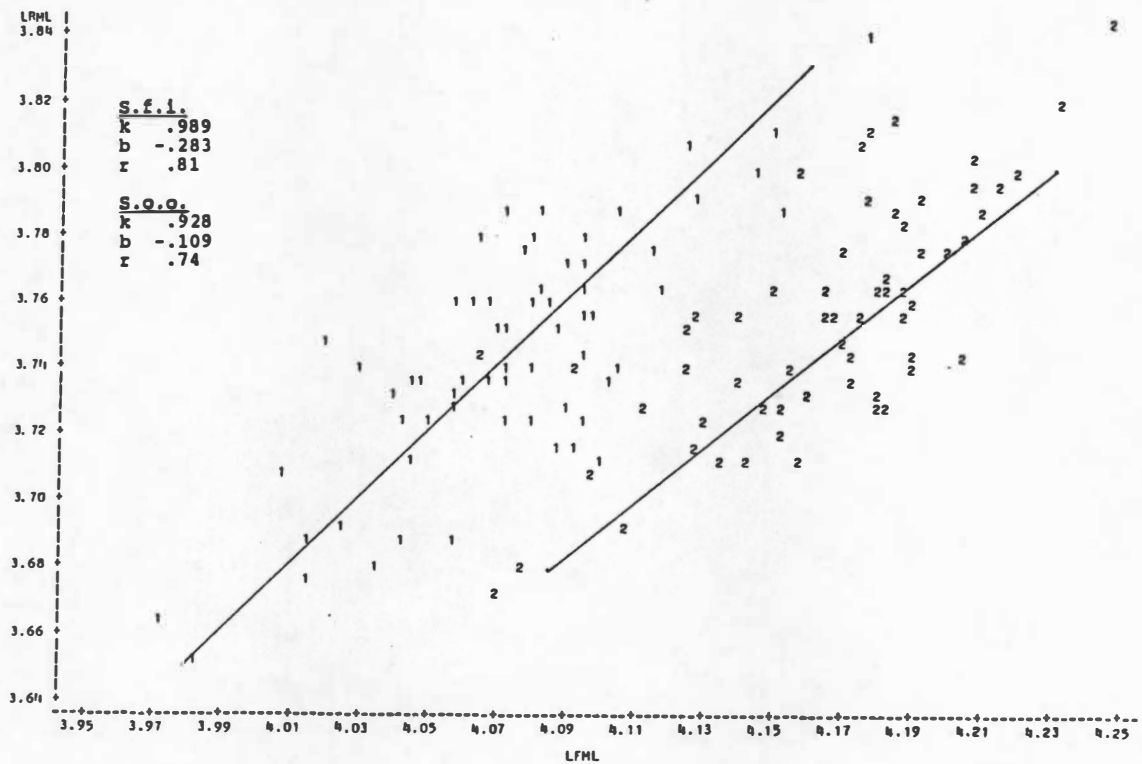


Figure 36. Reduced Major Axis regressions for the maximum length of the radius (LRML) on the maximum length of the femur (LFML).

Post-displacement, in this case, seems to describe the situation where the increase in size of S.o.oedipus relative to S.f.illigeri acts to retain the function of a longer radius.

The reduced major axis slopes for the maximum length of the tibia (LTML) for S.o.oedipus and S.f.illigeri are 0.958 and 1.052, respectively. The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic indicates that the slopes for the two species are not significantly different. An examination of the plots (Figure 37.) reveals that the regression lines for S.o.oedipus are post-displaced beneath those for S.f.illigeri.

The reduced major axis slopes for the maximum length of the ulna (LUML) for S.o.oedipus and S.f.illigeri are 0.875 and 0.900, respectively. The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic reveals that the slopes of the two species are not significantly different from each other. A qualitative visual examination of the plots (Figure 38.) indicates that the regression lines for S.o.oedipus are post-displaced beneath those of S.f.illigeri.

The reduced major axis slopes for the physiological length of the ulna (LUPL) for S.o.oedipus and S.f.illigeri are 0.954 and 0.993.

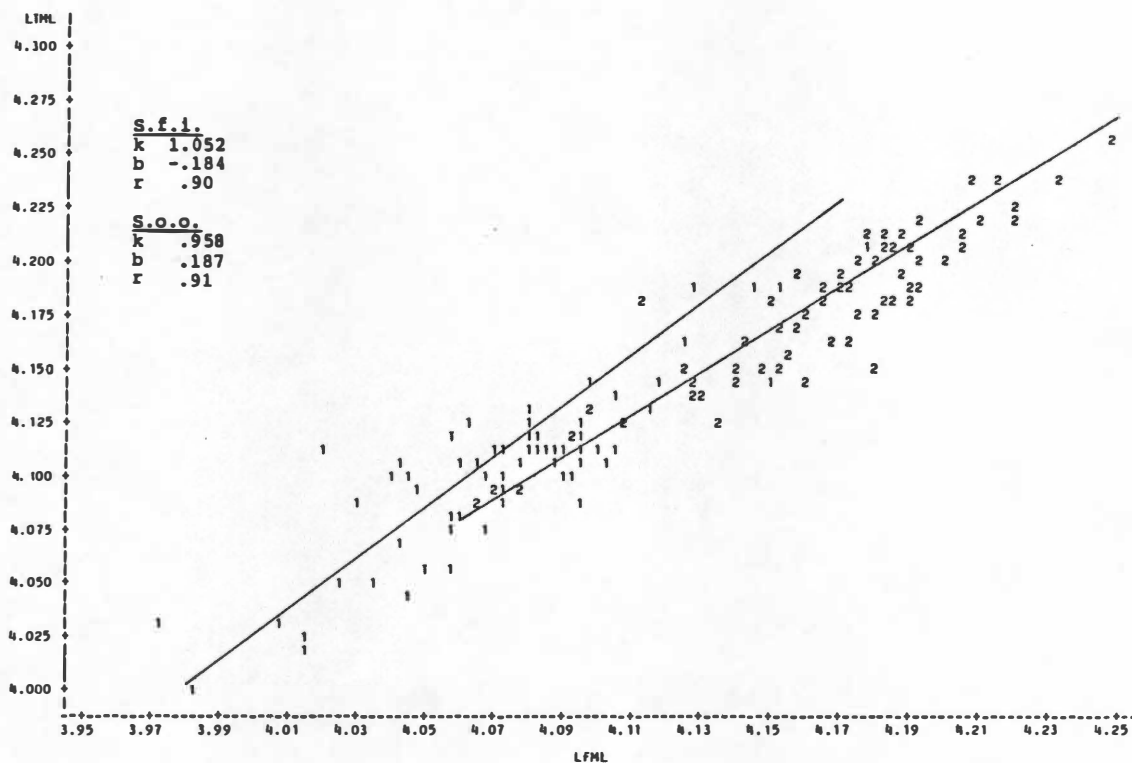


Figure 37. Reduced Major Axis regressions for the maximum length of the tibia (LTML) on the maximum length of the femur (LFML).

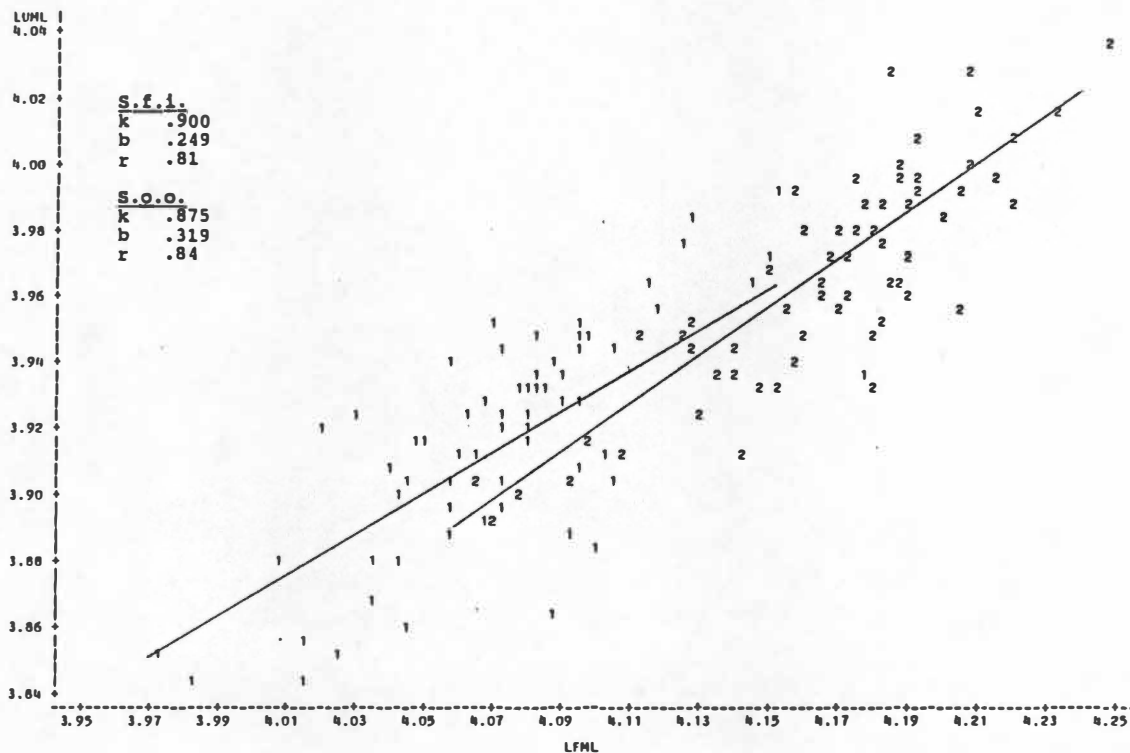


Figure 38. Reduced Major Axis regressions for the maximum length of the ulna (LUML) on the maximum length of the femur (LFML).

The 95% confidence interval indicates that the slopes are not significantly different from isometry (1.0). The Z-statistic indicates that the slopes are not significantly different. A visual examination of the plots (Figure 39.) indicates that the regression lines for S.o.oedipus are post-displaced beneath those for S.f.illigeri. In this case, S.o.oedipus is comparable to an "overgrown" S.f.illigeri.

The reduced major axis slopes for the maximum length of the scapula (LSML) for S.o.oedipus and S.f.illigeri are 1.293 and 1.516, respectively. The 95% confidence interval indicates that the slopes for S.o.oedipus and S.f.illigeri are not significantly different. The Z-statistic reveals that neither slope is significantly different from each other. A qualitative examination of the plots (Figure 40.) indicates that the regression lines for S.o.oedipus are an extension of the variability exhibited by S.f.illigeri. Hypermorphosis indicates an overall increase in size of the scapula of S.o.o., relative to S.f.i..

Recalling that the terms used to describe the preceeding dissociations are usually reserved for ontogenetic data sets, overall, the bivariate plots seem to indicate that Saguinus oedipus oedipus is a geometrically "overgrown" Saguinus fuscicollis illigeri.

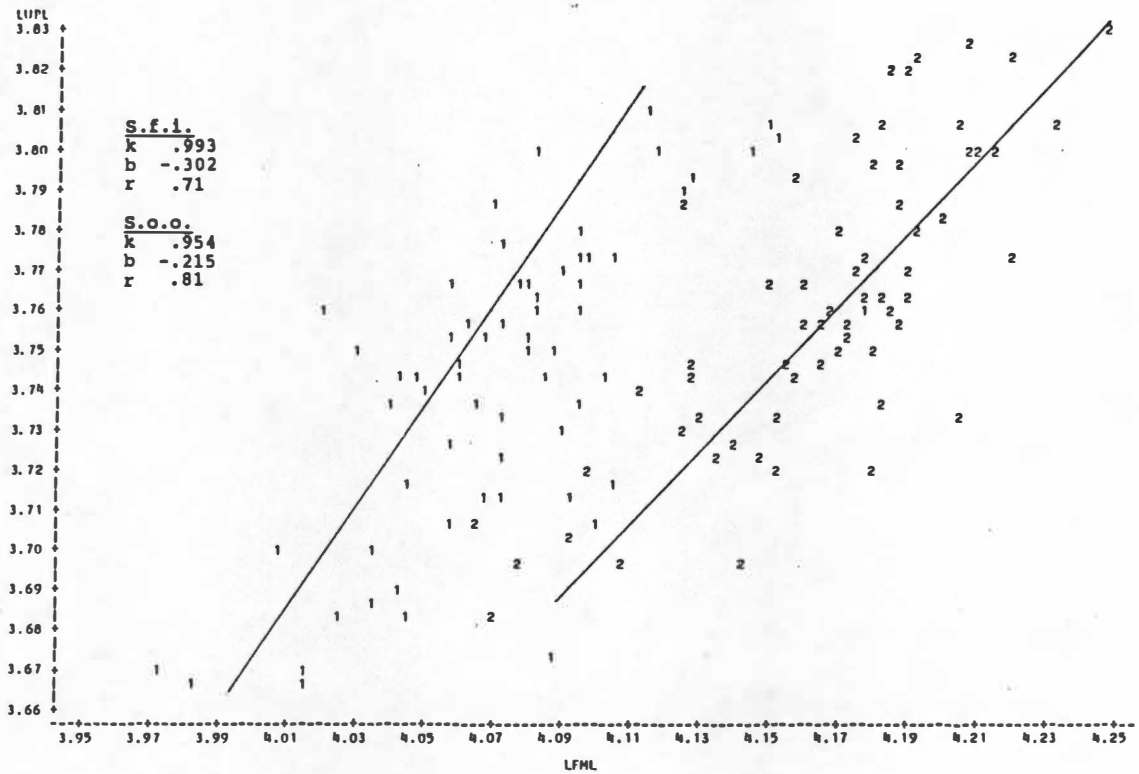


Figure 39. Reduced Major Axis regressions for the physiological length of the ulna (LUPL) on the maximum length of the femur (LFML).

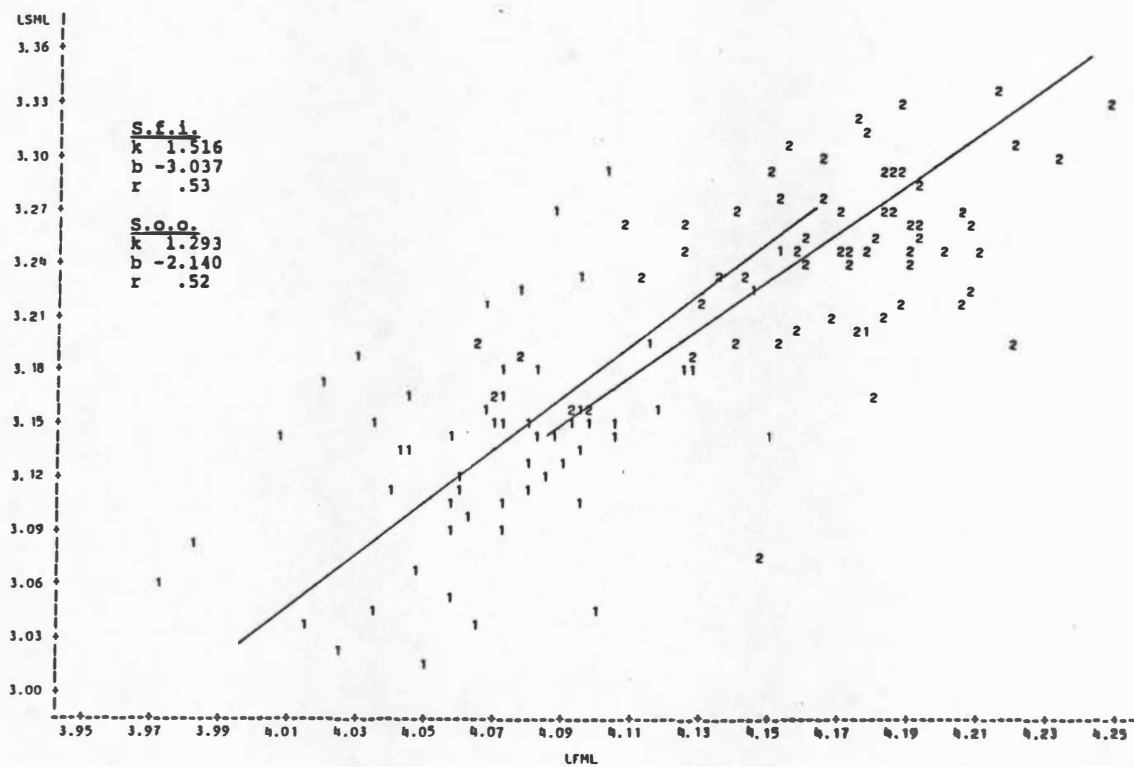


Figure 40. Reduced Major Axis regressions for the maximum length of the scapula (LSML) on the maximum length of the femur (LFML).

This interpretation is based on the qualitatively assessed observations of the plots for the "bone by bone", "limb" complexes, and the regressions utilizing femur maximum length as a generalized measure of body size. Interspecific quantitative analyses of the reduced major axis regression statistics, and qualitative observation of the plots for both S.o.oedipus and S.f.illigeri indicate that whatever locomotor differences exist between the species are not easily discerned.

However, the noted differences in the skeleton by Glassman (1983), may be exhibiting themselves in the statistically significant differences in slope values. It will be recalled that, out of thirty-seven bivariate regressions, only four presented statistically significant differences. The plots for the length of the infra-spinous line on scapula maximum length (Figure 14), mid-glenoid to the inferior angle length on scapula maximum length (Figure 16.), humerus maximum length on scapula maximum breadth (Figure 29.) and ulna physiological length on olecranon process to coronoid process length (Figure 32.). All exhibited significant differences in slopes. Interpretation of these differences is extremely difficult, and results will be presented conservatively.

The infraspinous length on scapula maximum length reduced major axis slope differences indicate that as the

size of the scapula increases, so does the length of the spine. This seems logical in that a larger animal would require an enlarged spine for the proper attachment of the upper limb muscles. However, in S.o.oedipus, the increase is more dramatic. A longer spine would allow for a greater area of muscle attachment. The muscles that attach on this structure are the supraspinatus, infraspinatus, and subscapularis. Both supraspinatus and infraspinatus attach to the greater tuberosity of the humerus, and are important for the rotation of the humerus. Subscapularis is also important for the motions related to climbing and grasping. An enlarged spine would, therefore, provide a greater area for this muscle to attach. Thus, enabling the animal to retain the function of this structure, as an area for muscle attachment, relative to an increase in size.

The increase of the mid-glenoid to inferior angle length, seems to be illustrating the same processs. An increase in the length of the angle relative to the length of the scapula gives a greater surface area for the attachment of muscles. The muscles that attach to this angle are the depressor scapulae and latissimus dorsi. These muscles are important for the extension of the upper limbs, and trunk specifically in grasping and climbing motions. Vertical movement of the trunk is also related to these muscle groups.

The growth of the humerus in S.o.oedipus relative S.f.illigeri seems to be related to the increase in breadth of the scapula. Rather, the humerus of S.o.oedipus is significantly larger than the humerus of S.f.illigeri relative to the increase in breadth. Both units appear to be experiencing rapid increases in size. The increase in size of the humerus in S.o.oedipus relative to that exhibited by S.f.illigeri, appears to be related to the increases of the scapular measures. A larger humerus would logically require a larger area for muscles to attach, and these muscle attachment areas are also increasing in size.

Glassman (1983) reports that significant differences were detected in muscle attachment areas in Saguinus oedipus oedipus and Saguinus fuscicollis illigeri, specifically in the olecranon process. A visual interpretation of the plot (Figure 32.) of ulna physiological length on olecranon process to coronoid process length seems to reveal a case of post-displacement, however, the slopes are both negatively allometric, thus indicating a possible change in function. Rather, as the physiological length of the ulna increases, the olecranon process is becoming elongated. An elongated olecranon process would allow for a greater area for the attachment of muscles that are involved in pronation and flexion. Specifically, the muscle group that is involved in flexion, flexor carpi ulnaris, flexor sublimis digitorum and flexor profundus digitorum. An elongation of

the olecranon process would presumably allow for this muscle group to increase flexion and pronation capabilities. Thus S.o.oedipus would be more adapted for the generation of the propulsional forces that are reported by Glassman (1983). This may lend support to the proposal that the anatomical differences in S.o.oedipus and S.f.illigeri are due to a greater morphological adaptation in S.o.oedipus for the generation of propulsion. This may be reflected in the observation that S.o.oedipus spends more time climbing and running along the terminal ends of the branches, while S.f.illigeri remains close to the trunk of the trees.

The adaptation to greater climbing and grasping abilities of S.o.oedipus relative to S.f.illigeri may also be reflected in the dietary habitats of the two species. S.o.oedipus eats primarily fruits and flowers which are located on the ends of branches, while S.f.illigeri eats mostly insects and some exudates which are located lower on the tree, and near the major trunk of the tree.

The results of the regressions utilizing femur maximum length as a measure of body size give support to the hypothesis that S.o.oedipus is an "overgrown" S.f.illigeri. Important to this observation is that all results indicate an overall increase in size. Also important is that the regressions indicate that function is not lost due to this increase in size.

In terms of locomotor adaptation, the post-displacement observed in the measures of the upper limbs and scapula may be related the significant differences in slope values between the measures mentioned above. Specifically, the post-displacement of the radius (Figure 36.), ulna (Figure 38), humerus (Figure 35.) and ulnar physiological length (Figure 39.). The post-displacement of the radius and humerus indicate that size increases without losing function. The proposed change in the olecranon process (Figure 32.), as an area of muscle attachment relates succinctly to the size increase in size of the radius. A greater ability for pronation and flexion relate to the increased size of the radius, and S.o.oedipus overall. One must not, however, discount the possibility that the heterochronic or geometrically similar patterns observed may be responses to selection for an overall size increase in S.o.oedipus relative to S.f.illigeri. If this is the case, then attempting to extrapolate locomotor differences, may be futile.

CHAPTER VI

SUMMARY

This thesis has attempted to explore the allometric variation exhibited in the postcranial skeleton in two species of tamarin, Saguinus oedipus oedipus and Saguinus Fuscicollis illigeri. The variability was investigated using allometric methodology, specifically reduced major axis regression and interpreted in terms of heterochronic processes. The question of anatomic diversity between the species was discussed in terms of locomotor variability. The data were analyzed using qualitative interpretations of the bivariate plots produced using the reduced major axis techniques. All conclusions presented below reflect the result from this study.

The "bone by bone" approach to the questions of allometric variability seem to indicate that S.o.oedipus is a geometrically "blown up" S.f.illigeri, and that by visual interpretation of the plots S.o.oedipus does not seem to lose any function as its overall size increases. In every case as bone size increases bone robusticity also increases geometrically, thereby preserving the functional equivalence of the elements in the larger species.

The "limb" complex results are also in general agreement with the hypothesis that S.o.oedips is an "overgrown" S.f.illigeri. However, significant slope differences are observed in certain comparisons. These differences are interpreted as perhaps relating to functional locomotor differences relative to size. In particular, the elongation of the olecranon process in S.o.oedipus is viewed as a change in function to facilitate the need for the generation of greater propulsive force in the forelimb of the larger species. This may be seen in the differing locomotor behaviors. Specifically, running and leaping along the terminal ends of the branches. The adaptation for the generation of greater propulsive forces may also be tied to the dietary zones the two species inhabit. Specifically, S.o.oedipus is noted for its exploitation of of the dietary resources located on the ends of branches, in particular flowers, and fruits. These dietary items are usually located in the higher regions of the canopy, while the diet of S.f.illigeri consists mainly of insects and exudates, which are usually found on the lower limbs. Also of importance is the areas of the cages that the two species inhabit in captivity. S.o.oedipus will take food that is placed on the floor of the cage and carry it to the highest branch available. S.o.oedipus will not even eat the food unless it has been take to the top of the

cage, while S.f.illigeri is less discriminating and will take food regardless of its location (Tardiff, 1986).

The results of scaling all limb bone measurements on femur maximum length present no significant differences in slope values. All results do, however, support the contention that S.o.oedipus is geometrically similar, and larger in overall size relative to S.f.illigeri. In every case, the function of all the limb bones is retained. Important is the post-displacement observed in the upper limb measurements.

One of the problems with the contentions stated above, is that these interpretations are usually based on ontogenetic data sets, and in this study static data were used. The interpretations presented given here are not presented in terms of growth, but rather represent statements of geometrical patterning. In order to make statements which more directly reflect allometric growth and its consequences the ages for all the animals must be known, and until the data set more complete in terms of individuals along the growth scale, assessment of the allometric variability of the genus Saguinus will remain inadequate.

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APPENDICES

APPENDIX A
SIMPLE STATISTICS

Table A-1. Simple statistics for Saguinus oedipus oedipus, data raw.

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C.V.
MALES							
AML	37	50.115	1.602	3.247	46.120	53.870	3.556
AME	37	7.764	0.344	0.118	7.080	8.590	4.427
RMH	37	42.904	1.630	2.657	39.380	46.690	3.799
UHL	37	52.697	1.781	3.172	49.090	56.640	3.380
FHL	37	64.239	2.658	7.067	58.260	69.970	4.138
FTL	37	63.866	2.598	6.751	58.250	69.910	4.068
IMH	37	65.207	2.494	6.219	59.740	70.670	3.824
BPE	37	9.301	0.332	0.110	8.300	9.800	3.573
BDE	37	5.899	0.199	0.039	5.420	6.360	3.366
RMH	37	61.909	2.313	5.348	55.880	67.760	3.735
MDS	37	3.692	0.273	0.074	3.220	4.120	7.387
MDH	37	3.821	0.248	0.062	3.360	4.410	6.493
MDH	37	6.635	0.277	0.077	6.050	7.110	4.173
EBR	37	10.966	0.502	0.252	9.670	11.960	4.580
ROH	37	4.750	0.206	0.043	4.270	5.090	4.344
BOP	37	3.721	0.291	0.084	3.210	4.520	7.810
MBO	37	2.649	0.270	0.073	2.150	3.260	10.191
WOP	37	5.363	0.260	0.068	4.830	5.950	4.857
ORL	37	5.059	0.274	0.075	4.450	5.670	5.420
OGL	37	5.034	0.289	0.084	4.520	5.480	5.742
APD	37	3.816	0.214	0.046	3.440	4.380	5.615
MLO	37	4.018	0.323	0.105	3.450	4.900	8.051
APS	37	3.858	0.235	0.055	3.500	4.350	6.100
HL.S	37	4.138	0.248	0.061	3.650	4.830	5.984
VHD	37	5.815	0.239	0.057	5.380	6.360	4.115
HHH	37	5.866	0.225	0.051	5.480	6.360	3.841
APL	37	8.551	0.345	0.119	7.690	9.380	4.035
APH	37	8.181	0.353	0.125	7.370	9.020	4.320
APH	37	5.608	0.426	0.181	4.660	6.680	7.595
HLH	37	3.192	0.272	0.074	2.780	3.770	8.527
CFI	37	17.470	1.324	1.754	14.600	20.870	7.581
SHL	37	25.882	1.465	2.145	21.570	28.060	5.658
SHD	37	25.378	0.959	0.920	23.120	26.970	3.780
SLS	37	29.928	1.048	1.098	27.060	31.680	3.501
SSL	37	12.722	1.072	1.149	11.060	14.770	8.424
ISL	37	16.468	1.248	1.557	13.510	19.130	7.578
GCR	37	3.827	0.190	0.036	3.410	4.170	4.963
GCH	37	5.622	0.326	0.107	5.060	6.360	5.807
GIL	37	30.288	1.201	1.443	27.210	31.920	3.966
UPL	37	42.960	1.540	2.371	39.820	46.030	3.584
IEB	37	9.955	0.356	0.127	8.830	10.600	3.578
LCS	37	3.573	0.415	0.172	3.060	4.860	11.641
MCS	37	2.372	0.158	0.025	2.000	2.780	6.674

Table A-1. (Continued).

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C.V.
FEMALES							
HHH	27	50.628	1.911	3.651	47.210	53.600	3.774
DUT	27	7.768	0.324	0.105	7.270	8.500	4.167
RHL	27	42.723	1.375	1.890	40.060	44.900	3.218
UHL	27	52.831	1.760	3.096	49.510	56.210	3.331
FHL	27	64.890	2.074	4.303	59.940	68.000	3.197
FTL	27	64.384	2.046	4.187	59.280	67.220	3.178
THL	27	65.603	2.231	4.977	61.410	69.160	3.441
BHL	27	9.218	0.252	0.064	8.780	9.670	2.735
BHF	27	5.778	0.245	0.060	5.210	6.330	4.241
MHL	27	62.304	2.243	5.029	58.160	66.230	3.599
HDS	27	3.673	0.244	0.060	3.160	4.310	6.646
HDM	27	3.826	0.246	0.061	3.290	4.380	6.429
HMH	27	6.535	0.295	0.087	6.040	7.210	4.512
FHR	27	10.927	0.458	0.210	10.130	11.930	4.195
RDH	27	4.752	0.170	0.029	4.380	5.010	3.568
ROP	27	3.656	0.263	0.069	3.220	4.410	7.180
FRD	27	2.653	0.235	0.055	2.170	3.180	8.873
WUP	27	5.231	0.246	0.060	4.760	5.580	4.696
ORL	27	5.003	0.304	0.092	4.480	5.810	6.068
OCL	27	4.979	0.401	0.161	4.010	5.670	8.054
APD	27	3.868	0.230	0.053	3.450	4.400	5.957
MLD	27	3.965	0.347	0.120	3.400	4.900	8.754
AP'S	27	3.841	0.187	0.035	3.400	4.220	4.865
MLS	27	4.130	0.274	0.075	3.630	4.710	6.644
VHD	27	5.871	0.264	0.070	5.300	6.600	4.498
HHO	27	5.937	0.267	0.071	5.350	6.620	4.490
APL	27	8.408	0.307	0.094	7.820	9.110	3.655
APH	27	8.119	0.294	0.087	7.490	8.640	3.625
APM	27	5.580	0.328	0.108	5.020	6.410	5.878
MLM	27	3.170	0.216	0.047	2.710	3.550	6.811
CTL	27	17.442	1.120	1.254	15.570	19.740	6.421
SHL	27	25.438	0.831	0.691	23.490	26.670	3.268
SHD	27	25.694	0.850	0.723	23.880	27.130	3.309
SLS	27	30.140	1.044	1.089	28.570	31.940	3.463
SSL	27	12.125	1.109	1.231	10.290	14.320	9.149
ISL	27	16.159	0.881	0.776	14.190	18.420	5.453
GCH	27	3.823	0.149	0.022	3.500	4.010	3.913
GCH	26	5.491	0.293	0.086	5.000	6.270	5.344
GIL	27	30.283	0.955	0.912	28.200	31.940	3.153
UPL	27	43.157	1.629	2.653	40.360	45.960	3.774
LEB	27	9.864	0.337	0.113	9.200	10.350	3.415
LCS	27	3.516	0.421	0.177	2.940	4.470	11.982
HCS	27	2.347	0.163	0.027	2.050	2.670	6.965

Table A-2. Simple statistics for Saguinus fuscicollis illigeri, data raw.

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C.V.
MALES							
IRL	32	87.265	1.455	2.117	84.190	50.540	3.078
BUE	32	7.079	0.363	0.133	6.480	8.100	5.151
RHL	32	42.435	1.507	2.517	38.580	46.490	3.739
URL	32	50.788	1.559	2.430	46.710	53.210	3.100
IRL	32	58.995	2.153	4.636	53.700	65.220	3.650
IRL	32	59.064	2.042	4.171	54.300	64.590	3.458
IRL	32	60.920	2.248	5.051	54.720	67.280	3.689
BPE	32	8.235	0.211	0.044	7.870	8.780	2.557
BUE	32	5.338	0.260	0.068	4.970	5.810	4.873
BHL	32	57.803	2.143	4.591	51.940	63.570	3.707
RHS	32	3.258	0.207	0.043	2.830	3.940	6.342
RHS	32	3.275	0.190	0.036	2.990	3.670	5.810
RHS	32	5.947	0.236	0.055	5.530	6.510	3.960
EBR	32	8.705	0.350	0.123	8.100	9.580	4.055
RHS	32	3.829	0.151	0.023	3.510	4.120	3.945
BOP	32	3.271	0.168	0.028	2.790	3.510	5.148
HBO	32	2.263	0.190	0.036	1.980	2.830	8.398
WOP	32	4.309	0.222	0.049	3.890	4.830	5.155
URL	32	4.253	0.218	0.048	3.890	4.720	5.133
OCL	32	4.128	0.186	0.035	3.690	4.430	4.504
APJ	32	3.772	0.171	0.029	3.470	4.130	4.521
MLD	32	3.609	0.289	0.083	3.170	4.330	8.002
APS	32	3.458	0.152	0.023	3.120	3.780	4.402
MLS	32	3.897	0.239	0.057	3.400	4.680	6.125
VHD	32	5.127	0.190	0.036	4.740	5.610	3.714
VHD	32	5.164	0.206	0.043	4.710	5.630	3.992
APL	32	7.526	0.316	0.100	6.650	8.100	4.193
APM	32	7.170	0.265	0.070	6.590	7.790	3.695
APM	32	4.864	0.342	0.117	4.330	5.790	7.040
MLM	32	2.796	0.180	0.032	2.410	3.160	6.430
CLL	32	17.817	1.467	2.152	14.450	20.960	8.234
SHL	32	23.171	1.554	2.414	20.590	26.980	6.705
SHB	32	23.583	0.921	0.849	21.860	25.600	3.907
SLS	32	27.387	0.941	0.885	25.180	29.050	3.435
SSL	32	10.799	1.234	1.522	8.780	13.740	11.424
ISL	32	15.600	0.938	0.879	13.840	18.070	6.012
GCB	32	3.560	0.166	0.028	3.250	3.870	4.661
GCH	32	5.215	0.371	0.138	4.590	6.090	7.112
GIL	32	28.344	1.517	2.302	25.400	31.860	5.353
UPL	32	42.408	1.506	2.268	39.090	45.080	3.552
LEB	32	8.947	0.306	0.094	8.220	9.530	3.420
LCS	32	3.148	0.281	0.079	2.660	3.960	8.936
HCS	32	2.136	0.107	0.011	1.930	2.400	4.998

Table A-2. (Continued).

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C.V.
FEMALES							
WFL	34	47.519	1.754	3.075	43.990	50.910	3.690
BUF	34	7.183	0.244	0.060	6.430	7.620	3.404
RMFL	34	42.176	1.587	2.518	39.010	45.190	3.762
WFL	34	50.306	1.860	3.458	46.620	54.220	3.696
FTL	34	58.646	2.316	5.362	53.060	63.610	3.949
IML	34	58.587	2.372	5.624	52.640	63.570	4.048
UPE	34	60.189	2.543	6.465	55.790	66.060	4.274
BOF	34	8.194	0.307	0.094	7.460	8.810	3.745
BMFL	34	5.278	0.184	0.034	4.860	5.580	3.491
MDS	34	57.159	2.367	5.600	53.130	62.630	4.140
MDH	34	3.310	0.231	0.053	2.840	3.730	6.972
EDR	34	3.269	0.193	0.037	2.880	3.580	5.896
RDH	34	5.939	0.231	0.053	5.340	6.350	3.890
ROP	34	8.690	0.385	0.149	7.770	9.570	4.436
MDO	34	3.859	0.169	0.028	3.470	4.150	4.368
WOP	34	3.213	0.224	0.050	2.780	3.810	6.972
OCL	34	2.281	0.264	0.070	1.850	3.090	11.582
AFD	34	4.454	0.193	0.037	4.050	4.900	4.326
MLD	34	4.188	0.261	0.068	3.650	4.680	6.234
AFS	34	4.100	0.249	0.062	3.680	4.570	6.061
MIS	34	3.777	0.233	0.054	3.400	4.410	6.164
VHD	34	3.599	0.289	0.083	3.170	4.390	8.023
HHD	34	3.553	0.249	0.062	3.090	4.140	6.995
APL	34	3.985	0.342	0.117	3.510	4.740	8.577
APM	34	5.130	0.163	0.027	4.830	5.460	3.186
MLM	34	5.161	0.192	0.037	4.820	5.470	3.720
SHL	34	7.334	0.308	0.095	6.730	7.950	4.197
SLS	34	7.127	0.253	0.064	6.600	7.720	3.544
SSL	34	4.933	0.371	0.138	4.170	5.930	7.529
GLL	34	2.790	0.221	0.049	2.400	3.200	7.923
SHB	34	17.204	1.795	3.222	13.670	20.470	10.434
SLS	34	22.991	1.096	1.201	20.380	25.650	4.767
SSL	34	23.450	1.160	1.346	21.520	25.890	4.948
GLL	34	27.264	1.255	1.574	24.790	29.510	4.602
SHL	34	10.397	0.966	0.933	8.420	12.360	9.291
SSL	34	15.204	0.940	0.884	13.580	17.460	6.182
GLL	34	3.546	0.201	0.040	3.260	4.140	5.661
SHL	34	5.124	0.351	0.123	4.530	6.070	6.842
SSL	34	28.001	1.575	2.481	24.480	31.030	5.625
GLL	34	42.131	1.656	2.741	39.060	45.050	3.930
FFB	34	8.807	0.315	0.099	7.970	9.430	3.572
LCS	34	3.099	0.366	0.134	2.520	4.410	11.815
MCS	34	2.095	0.123	0.015	1.850	2.330	5.885

Table A-3. Simple statistics for Saguinus oedipus oedipus, data logged.

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C.V.
FEMALES							
IMHL	27	3.925	0.038	0.001	3.853	3.982	0.965
IBUF	27	2.089	0.082	0.002	1.988	2.140	2.026
IRHL	27	3.754	0.032	0.001	3.690	3.804	0.857
LIHL	27	3.967	0.033	0.001	3.902	4.030	0.841
LFHL	27	4.172	0.032	0.001	4.093	4.220	0.776
LFHL	27	4.164	0.032	0.001	4.082	4.208	0.772
LTML	27	4.183	0.034	0.001	4.118	4.236	0.817
LBPE	27	2.221	0.027	0.001	2.172	2.269	1.233
IBUF	27	1.753	0.043	0.002	1.651	1.845	2.427
IRHL	27	4.131	0.036	0.001	4.063	4.193	0.875
IMDS	27	1.299	0.066	0.004	1.151	1.461	5.103
IMDH	27	1.340	0.065	0.004	1.163	1.477	4.833
IMDH	27	1.876	0.045	0.002	1.798	1.975	2.398
LEBR	27	2.390	0.042	0.002	2.316	2.479	1.751
IRDH	27	1.558	0.036	0.001	1.477	1.611	2.307
IDOP	27	1.294	0.070	0.005	1.169	1.484	5.440
IMHO	27	0.972	0.089	0.008	0.775	1.157	9.124
IWOP	27	1.654	0.047	0.002	1.560	1.719	2.864
IORL	27	1.608	0.060	0.004	1.500	1.760	3.756
LOCL	27	1.602	0.083	0.007	1.389	1.735	5.189
IAFD	27	1.351	0.060	0.004	1.238	1.482	4.412
IMLO	27	1.374	0.085	0.007	1.224	1.589	6.219
IAFS	27	1.345	0.049	0.002	1.224	1.440	3.636
IMLS	27	1.416	0.067	0.004	1.289	1.550	4.716
IVHD	27	1.769	0.045	0.002	1.668	1.887	2.524
LIHD	27	1.780	0.045	0.002	1.677	1.890	2.513
LAPL	27	2.129	0.036	0.001	2.057	2.209	1.714
IAPM	27	2.094	0.036	0.001	2.014	2.156	1.734
IAPM	27	1.717	0.058	0.003	1.613	1.858	3.386
IMLM	27	1.151	0.069	0.005	0.997	1.267	5.996
ICFL	27	2.857	0.064	0.004	2.745	2.983	2.230
ISHL	27	3.236	0.033	0.001	3.157	3.284	1.022
ISHB	27	3.246	0.033	0.001	3.173	3.301	1.021
ISLS	27	3.405	0.035	0.001	3.352	3.464	1.014
ISSL	27	2.491	0.090	0.008	2.331	2.662	3.621
ISLS	27	2.781	0.054	0.003	2.653	2.913	1.954
IGCR	27	1.340	0.040	0.002	1.253	1.389	2.951
IGCH	26	1.702	0.052	0.003	1.609	1.836	3.077
IGIL	27	3.410	0.032	0.001	3.339	3.464	0.725
IUPL	27	3.764	0.038	0.001	3.698	3.828	1.000
LEFB	27	2.288	0.034	0.001	2.219	2.337	1.502
LLCS	27	1.251	0.115	0.013	1.078	1.497	9.181
LMCS	27	0.851	0.070	0.005	0.718	0.982	8.174

Table A-3. (Continued).

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C. V.
MALES							
IMHL	37	3.914	0.036	0.001	3.831	3.987	0.920
IMHE	37	2.048	0.044	0.002	1.957	2.151	2.162
IMHI	37	3.758	0.038	0.001	3.673	3.844	1.010
IMHL	37	3.964	0.034	0.001	3.894	4.037	0.854
IFML	37	4.162	0.042	0.002	4.065	4.248	1.004
IFTL	37	4.156	0.041	0.002	4.065	4.247	0.987
IFHL	37	4.177	0.038	0.001	4.090	4.258	0.921
IMFE	37	2.229	0.036	0.001	2.116	2.282	1.623
IMDE	37	1.774	0.034	0.001	1.690	1.850	1.908
IMHL	37	4.125	0.038	0.001	4.023	4.216	0.911
IMDS	37	1.304	0.074	0.005	1.169	1.416	5.663
IMDH	37	1.338	0.064	0.004	1.212	1.484	4.814
IMDH	37	1.891	0.042	0.002	1.800	1.962	2.207
IBBR	37	2.394	0.046	0.002	2.269	2.482	1.913
IBDH	37	1.557	0.044	0.002	1.452	1.627	2.809
IBOP	37	1.311	0.076	0.006	1.166	1.509	5.830
IBBO	37	0.969	0.101	0.010	0.765	1.182	10.377
LBOP	37	1.678	0.049	0.002	1.575	1.783	2.903
IBRL	37	1.620	0.054	0.003	1.493	1.735	3.364
IBCL	37	1.615	0.057	0.003	1.509	1.701	3.560
IBPD	37	1.338	0.056	0.003	1.235	1.477	4.159
IBLD	37	1.388	0.080	0.006	1.238	1.589	5.741
IBPS	37	1.348	0.060	0.004	1.253	1.470	4.448
IBLS	37	1.418	0.059	0.004	1.295	1.575	4.172
IBVD	37	1.760	0.041	0.002	1.683	1.850	2.333
IBHD	37	1.768	0.038	0.001	1.701	1.850	2.161
IBPL	37	2.145	0.040	0.002	2.040	2.239	1.882
IBPH	37	2.101	0.044	0.002	1.997	2.199	2.074
IBPH	37	1.721	0.076	0.006	1.539	1.899	4.432
IBLM	37	1.157	0.084	0.007	1.022	1.327	7.245
IBFL	37	2.858	0.075	0.006	2.681	3.038	2.634
IBHL	37	3.252	0.058	0.003	3.071	3.334	1.782
IBHB	37	3.233	0.038	0.001	3.141	3.295	1.177
IBLS	37	3.398	0.035	0.001	3.298	3.456	1.041
IBSL	37	2.540	0.085	0.007	2.403	2.693	3.336
IBSL	37	2.799	0.077	0.006	2.603	2.951	2.750
IBGB	37	1.341	0.050	0.002	1.235	1.428	3.726
IBGH	37	1.725	0.057	0.003	1.621	1.850	3.331
IBGL	37	3.410	0.040	0.002	3.304	3.463	1.183
IBPL	37	3.760	0.036	0.001	3.684	3.829	0.955
IBFB	37	2.297	0.036	0.001	2.178	2.361	1.582
IBCS	37	1.267	0.109	0.012	1.118	1.581	8.588
IBCS	37	0.862	0.066	0.004	0.693	1.022	7.702

Table A-4. Simple statistics for Saguinus fuscicollis illigeri, data logged.

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C.V.
FEMALES							
IJHL	34	3.860	0.037	0.001	3.784	3.930	0.956
IBUE	34	1.971	0.035	0.001	1.861	2.031	1.755
IRHL	34	3.741	0.038	0.001	3.664	3.811	1.010
IUMI	34	3.917	0.037	0.001	3.842	3.993	0.916
IFMI	34	4.071	0.040	0.002	3.971	4.153	0.972
IFTL	34	4.070	0.041	0.002	3.963	4.152	1.000
ITHL	34	4.097	0.042	0.002	4.022	4.191	1.029
IDPE	34	2.103	0.038	0.001	2.010	2.176	1.793
IDDE	34	1.663	0.035	0.001	1.581	1.719	2.119
IDHL	34	4.045	0.041	0.002	3.973	4.137	1.021
IMDS	34	1.195	0.070	0.005	1.044	1.316	5.865
IMDI	34	1.183	0.059	0.004	1.058	1.275	5.018
IMDI	34	1.781	0.039	0.002	1.675	1.848	2.207
ICRR	34	2.161	0.044	0.002	2.050	2.259	2.039
IRDI	34	1.349	0.044	0.002	1.244	1.423	3.277
IRDP	34	1.165	0.069	0.005	1.022	1.338	5.948
IRBO	34	0.818	0.113	0.013	0.615	1.128	13.750
IWOP	34	1.493	0.043	0.002	1.399	1.589	2.905
IORL	34	1.430	0.063	0.004	1.295	1.543	4.382
IOCL	34	1.409	0.060	0.004	1.303	1.520	4.273
IAPD	34	1.327	0.060	0.004	1.224	1.484	4.557
IRLD	34	1.278	0.078	0.006	1.154	1.479	6.093
IAPS	34	1.266	0.069	0.005	1.128	1.421	5.472
IHLS	34	1.379	0.084	0.007	1.256	1.556	6.093
IYHD	34	1.635	0.032	0.001	1.575	1.697	1.943
IYHD	34	1.640	0.037	0.001	1.573	1.699	2.270
IAPL	34	1.992	0.042	0.002	1.907	2.073	2.106
IAPH	34	1.963	0.035	0.001	1.887	2.044	1.800
IAPH	34	1.593	0.074	0.005	1.428	1.780	4.621
IHLH	34	1.023	0.079	0.006	0.875	1.163	7.730
LCFL	34	2.840	0.104	0.011	2.615	3.019	3.663
ISHL	34	3.134	0.048	0.002	3.015	3.245	1.537
LSHB	34	3.154	0.049	0.002	3.069	3.254	1.567
LSLS	34	3.305	0.046	0.002	3.210	3.385	1.396
ISSI	34	2.337	0.094	0.009	2.131	2.514	4.028
ISL	34	2.720	0.062	0.004	2.609	2.860	2.271
ICCB	34	1.264	0.055	0.003	1.182	1.421	4.355
ICCH	34	1.632	0.067	0.004	1.511	1.803	4.110
ICIL	34	3.331	0.057	0.003	3.198	3.435	1.704
IUPL	34	3.740	0.039	0.002	3.665	3.808	1.055
IEB	34	2.175	0.036	0.001	2.076	2.244	1.654
ILCS	34	1.125	0.112	0.013	0.924	1.484	9.948
LMCS	34	0.738	0.059	0.003	0.615	0.846	7.987

Table A-4. (Continued).

VARIABLE	N	MEAN	STANDARD DEVIATION	VARIANCE	MINIMUM VALUE	MAXIMUM VALUE	C.V.
MALES							
THHL	32	3.855	0.031	0.001	3.788	3.923	0.801
LBUE	32	1.956	0.051	0.003	1.869	2.092	2.592
IRHL	32	3.747	0.037	0.001	3.653	3.839	0.998
LUHL	32	3.917	0.031	0.001	3.844	3.974	0.198
LFHL	32	4.077	0.036	0.001	3.983	4.178	0.891
LFIL	32	4.078	0.035	0.001	3.995	4.168	0.847
LIML	32	4.109	0.037	0.001	4.002	4.209	0.897
LBPE	32	2.108	0.026	0.001	2.063	2.172	1.210
LBDE	32	1.674	0.048	0.002	1.603	1.760	2.897
LBML	32	4.056	0.037	0.001	3.950	4.152	0.914
IMDS	32	1.179	0.062	0.004	1.040	1.371	5.269
IMDM	32	1.185	0.057	0.003	1.095	1.300	4.853
IMDH	32	1.782	0.040	0.002	1.710	1.873	2.221
LEBR	32	2.163	0.040	0.002	2.092	2.260	1.836
LRDH	32	1.342	0.039	0.002	1.256	1.416	2.938
LBOP	32	1.184	0.053	0.003	1.026	1.256	4.450
LBDO	32	0.813	0.082	0.007	0.683	1.040	10.049
LBUP	32	1.459	0.051	0.003	1.358	1.575	3.501
LBRI	32	1.406	0.051	0.003	1.358	1.552	3.559
LOCL	32	1.417	0.045	0.002	1.306	1.488	3.207
IAFD	32	1.327	0.045	0.002	1.244	1.418	3.401
IMLD	32	1.280	0.078	0.006	1.154	1.466	6.079
IAFS	32	1.240	0.044	0.002	1.138	1.330	3.557
LMHS	32	1.358	0.060	0.004	1.224	1.543	4.399
LVHD	32	1.634	0.037	0.001	1.556	1.725	2.250
LVHD	32	1.641	0.040	0.002	1.550	1.728	2.422
LAPL	32	2.018	0.042	0.002	1.895	2.092	2.102
LAPH	32	1.969	0.037	0.001	1.886	2.053	1.875
LAPN	32	1.579	0.069	0.005	1.466	1.756	4.356
LMHM	32	1.026	0.065	0.004	0.880	1.151	6.300
LCFI	32	2.877	0.083	0.007	2.671	3.043	2.870
LSHL	32	3.141	0.066	0.004	3.025	3.295	2.115
LSMB	32	3.160	0.039	0.002	3.085	3.243	1.235
LSLS	32	3.310	0.034	0.001	3.226	3.369	1.042
LSL	32	2.373	0.112	0.013	2.172	2.620	4.722
LSL	32	2.746	0.059	0.004	2.628	2.894	2.159
LCGB	32	1.269	0.046	0.002	1.179	1.353	3.660
LCCH	32	1.649	0.071	0.005	1.524	1.807	4.286
LCIL	32	3.303	0.053	0.003	3.235	3.461	1.592
LUPL	32	3.747	0.036	0.001	3.666	3.808	0.957
LEEB	32	2.191	0.034	0.001	2.107	2.254	1.571
LLCS	32	1.143	0.086	0.007	0.978	1.376	7.558
LMCS	32	0.758	0.050	0.002	0.658	0.875	6.537

APPENDIX B
COVARIANCE MATRICES

Within species covariance matrix, Saguinus oedipus
oedipus.

	LMHL	LBUE	LRML	LUML	LFML	LFTL	LTML	LBPE	LBDE	LBHL	LMOS
LMHL	.00112										
LBUE	939E-6	.00106									
LRML	.00104	865E-6	.00127								
LUML	.00104	924E-6	.00106	.00112							
LFML	.00118	.00115	.00101	.00109	.00147						
LFTL	.00117	.00111	.00102	.00108	.00142	.00128					
LTML	.00116	.00107	.00106	0.0011	.00128	.00128	.00128				
LBPE	530E-6	868E-6	481E-6	565E-6	767E-6	742E-6	762E-6				
LBDE	574E-6	662E-6	617E-6	713E-6	730E-6	715E-6	752E-6	760E-6			
LBHL	.00118	.00105	.00105	0.0011	.00127	.00125	.00132	713E-6	711E-6		
LMOS	267E-6	.00188	0.0012	.00109	.00118	.00122	.00122	.00106	875E-6	.00123	
LMH4	916E-6	.00111	939E-6	825E-6	942E-6	.00102	987E-6	701E-6	540E-6	.00101	.00311
LMH5	416E-6	482E-6	462E-6	433E-6	362E-6	345E-6	366E-6	225E-6	166E-6	350E-6	0.0013
LMH6	748E-6	.00122	652E-6	789E-6	.00102	0.001	.00104	.00103	.00111	0.001	.00139
LMH7	811E-6	.00104	844E-6	894E-6	976E-6	937E-6	887E-6	800E-6	758E-6	860E-6	.00131
LMH8	.00121	.00149	.00134	.00127	.00124	.00126	.00149	.00112	.00158	.00149	.00223
LMH9	.00107	532E-6	997E-6	.00104	973E-6	951E-6	0.0011	727E-6	799E-6	.00117	.00169
LMH0	594E-6	962E-6	678E-6	897E-6	738E-6	756E-6	688E-6	586E-6	919E-6	708E-6	.00111
LMH1	.00103	.00117	950E-6	917E-6	100E-5	.00101	933E-6	817E-6	435E-6	915E-6	.00149
LMH2	930E-6	.00146	949E-6	.00101	.00112	.00114	.00118	706E-6	.00132	.00101	.00152
LMH3	405E-6	993E-6	559E-6	569E-6	411E-6	447E-6	500E-6	582E-6	616E-6	506E-6	0.0024
LMH4	.00106	.00153	.00127	.00105	.00116	.00123	0.0013	.00123	.00114	.00128	.00364
LMH5	758E-6	.00141	691E-6	744E-6	819E-6	805E-6	951E-6	869E-6	700E-6	942E-6	0.0028
LMH6	852E-6	.00169	953E-6	895E-6	.00107	.00105	.00107	.00101	788E-6	.00108	.00317
LMH7	812E-6	0.0012	559E-6	770E-6	927E-6	892E-6	841E-6	824E-6	644E-6	833E-6	.00154
LMH8	798E-6	.00122	593E-6	763E-6	973E-6	923E-6	867E-6	850E-6	688E-6	839E-6	.00151
LMH9	770E-6	.00117	764E-6	811E-6	996E-6	988E-6	968E-6	949E-6	935E-6	890E-6	.00115
LMH0	629E-6	963E-6	589E-6	677E-6	907E-6	856E-6	873E-6	894E-6	829E-6	805E-6	.00108
LMH1	.00106	.00185	.00116	.00113	0.0013	.00126	.00123	919E-6	.00116	.00126	.00302
LMH2	320E-6	.00129	660E-6	657E-6	707E-6	701E-6	781E-6	894E-6	.00105	752E-6	.00119
LMH3	.00105	.00103	816E-6	911E-6	.00111	.00117	0.0013	999E-6	0.0011	.00112	.00148
LMH4	957E-6	.00115	939E-6	921E-6	984E-6	.00106	0.0011	902E-6	796E-6	.00103	.00191
LMH5	914E-6	857E-6	733E-6	803E-6	.00106	.00103	944E-6	590E-6	527E-6	964E-6	.00113
LMH6	872E-6	794E-6	713E-6	747E-6	959E-6	948E-6	878E-6	547E-6	411E-6	875E-6	916E-6
LMH7	893E-6	.00112	.00114	.00114	993E-6	.00104	788E-6	438E-6	952E-6	708E-6	.00185
LMH8	.00116	.00133	.00114	.00109	.00135	.00138	.00154	.00125	973E-6	.00141	.00167
LMH9	382E-6	688E-6	396E-6	340E-6	338E-6	425E-6	4419E-6	586E-6	531E-6	346E-6	9C4E-6
LMH0	568E-6	280E-6	422E-6	588E-6	404E-6	417E-6	549E-6	330E-6	780E-6	541E-6	817E-6
LMH1	895E-6	853E-6	770E-6	811E-6	991E-6	.00101	985E-6	723E-6	698E-6	952E-6	0.0011
LMH2	0.0011	871E-6	.00109	.00115	.00107	.00106	0.0011	511E-6	730E-6	.00113	949E-6
LMH3	767E-6	969E-6	608E-6	721E-6	869E-6	875E-6	884E-6	898E-6	744E-6	816E-6	947E-6
LMH4	-77E-6	338E-6	224E-6	128E-6	-17E-6	885E-7	-35E-6	151E-6	279E-6	-23E-6	.00304
LMH5	741E-6	945E-6	941E-6	938E-6	781E-6	779E-6	746E-6	511E-6	593E-6	753E-6	.00248

Within species covariance matrix S.o.o. (Continued).

[illegible]

Within species covariance matrix S.o.o. (Continued).

[illegible]

Within species covariance matrix S.o.o. (Continued).

	LSSL	LSSS	LISL	LGCB	LGIL	LUPL	LFEB	LLCS	LHCS
IIML									
IDUE									
ICBL									
IDBH									
IFAL									
ITTI									
ITML									
IDPT									
IDBF									
IBVL									
IWDS									
IDWHI									
IDWH									
IFHR									
IDHH									
IDOP									
IDHO									
IDOP									
IDRI									
IDCL									
IAFD									
IMUO									
IAS									
ILS									
IYHD									
IHYD									
IAPL									
IATH									
IATN									
IDRH									
IGFI									
LSHL									
LSHB									
LSLS	.00173								
LSSL	715E-6	.00804							
LSSL	.00121	517E-6	.00475						
LCGR	796E-6	325E-6	.00134	0.0021					
CGHI	491E-6	.00191	950E-6	505E-6	.00316				
CGII	.00106	.00118	.00159	547E-6	573E-6	.00134			
IUFL	711E-6	.00114	926E-6	271E-6	432E-6	839E-6	.00129		
LIIB	588E-6	597E-6	.00113	534E-6	518E-6	661E-6	- .0002	.00128	
LICS	204E-6	.00421	-34E-6	861E-6	.00313	213E-7	-.0002	.01234	
HGCS	740E-6	.00148	.00103	753E-6	0.0012	436E-6	801E-6	.00339	.004136

Within species covariance matrix Saguinus fuscicollis
illigeri.

	LHHL	LBUE	LRHL	LUHL	LFML	LFLL	LTML	LBPE	LBDE	LBHL	LMDS
LHHL	.00115										
LHUC	340E-6	.00189									
LHML	960E-6	239E-6	0.0014								
LHUL	994E-6	492E-6	.0012	.0016							
LFHL	0.001	431E-6	.0011	976E-6	.00143						
LFLL	.00101	376E-6	.00114	.00102	0.0014	.00143					
LFML	.00112	599E-6	.00127	.00114	.00131	.00131	.00159				
LFPL	503E-6	649E-6	437E-6	491E-6	576E-6	542E-6	752E-6	.00104			
LFUL	522E-6	934E-6	370E-6	416E-6	589E-6	579E-6	589E-6	681E-6	.00178		
LBUE	.00109	599E-6	.00126	.00113	0.0013	0.0013	.00155	766E-6	607E-6	.00155	
LBHL	881E-6	544E-6	884E-6	825E-6	689E-6	688E-6	906E-6	385E-6	422E-6	908E-6	.00439
LBDE	767E-6	638E-6	604E-6	782E-6	598E-6	683E-6	854E-6	390E-6	390E-6	838E-6	.00188
LBHL	396E-6	677E-6	181E-6	121E-6	286E-6	189E-6	423E-6	450E-6	374E-6	384E-6	179E-6
LBML	731E-6	.00102	759E-6	702E-6	737E-6	751E-6	983E-6	774E-6	674E-6	941E-6	.00103
LBPL	475E-6	600E-6	497E-6	342E-6	466E-6	410E-6	481E-6	652E-6	696E-6	462E-6	214E-6
LBUL	231E-6	569E-6	670E-6	482E-6	219E-6	221E-6	414E-6	664E-6	606E-6	416E-6	906E-6
LFML	622E-6	- .0004	.00104	501E-6	451E-6	598E-6	393E-6	- .0003	- .0005	416E-6	.00154
LFPL	563E-6	604E-6	378E-6	289E-6	317E-6	319E-6	362E-6	423E-6	371E-6	352E-6	770E-6
LFUL	419E-6	242E-6	539E-6	144E-6	623E-6	566E-6	889E-6	379E-6	440E-6	851E-6	137E-6
LBPE	315E-6	523E-6	196E-6	443E-6	416E-6	518E-6	343E-6	651E-6	597E-6	388E-6	- .0002
LBDE	868E-6	395E-6	680E-6	729E-6	769E-6	744E-6	925E-6	374E-6	598E-6	863E-6	.00176
LBHL	844E-6	649E-6	888E-6	884E-6	899E-6	.00104	.00127	925E-6	989E-6	.00127	.00228
LBML	.00106	721E-6	950E-6	961E-6	.00106	0.0011	.00113	788E-6	955E-6	.00112	.00211
LBPL	914E-6	.00119	600E-6	921E-6	866E-6	792E-6	.00117	0.0011	675E-6	.00118	.00253
LBUL	572E-6	476E-6	451E-6	381E-6	679E-6	598E-6	723E-6	679E-6	502E-6	670E-6	541E-6
LFML	522E-6	641E-6	383E-6	351E-6	695E-6	560E-6	716E-6	728E-6	591E-6	669E-6	564E-6
LFPL	438E-6	691E-6	441E-6	450E-6	694E-6	678E-6	775E-6	776E-6	888E-6	764E-6	823E-6
LFUL	515E-6	536E-6	473E-6	433E-6	705E-6	663E-6	724E-6	649E-6	656E-6	691E-6	743E-6
LBPE	.00113	.00106	712E-6	843E-6	706E-6	666E-6	.00106	851E-6	511E-6	.00103	.00239
LBDE	957E-6	716E-6	898E-6	862E-6	854E-6	865E-6	.00138	879E-6	543E-6	.00137	.00239
LBHL	701E-6	382E-6	939E-6	0.0011	.00135	.00143	.00132	553E-6	990E-6	.00124	.00117
LBML	919E-6	886E-6	880E-6	821E-6	.00115	.00109	.00113	751E-6	.00102	.00115	876E-6
LBPL	.00104	277E-6	.00104	846E-6	.00104	.00107	.00118	346E-6	521E-6	.00114	810E-6
LBUL	963E-6	288E-6	899E-6	758E-6	.00104	.00105	.00106	288E-6	474E-6	.00101	825E-6
LFML	814E-6	749E-6	890E-6	979E-6	.00112	0.0012	972E-6	601E-6	742E-6	.00102	623E-6
LFPL	512E-6	557E-6	648E-6	501E-6	770E-6	739E-6	812E-6	662E-6	631E-6	.00102	531E-6
LFUL	565E-6	757E-6	316E-6	241E-6	599E-6	575E-6	684E-6	466E-6	710E-6	631E-6	468E-6
LBPE	446E-6	831E-6	638E-6	235E-6	455E-6	379E-6	748E-6	584E-6	434E-6	760E-6	725E-6
LBDE	.00121	449E-6	.00128	.00101	.00142	.00135	.00151	734E-6	697E-6	.00146	937E-6
LBHL	959E-6	348E-6	.00121	.00123	997E-6	.00105	0.0012	443E-6	426E-6	.00119	811E-6
LBML	350E-6	487E-6	394E-6	408E-6	498E-6	456E-6	605E-6	802E-6	768E-6	644E-6	335E-6
LBPL	824E-6	-20E-6	0.0011	533E-6	931E-6	900E-6	863E-6	673E-6	- .0002	818E-6	0.0019
LBUL	545E-6	- .0002	.00105	813E-6	452E-6	551E-6	765E-6	295E-6	-36E-6	731E-6	.00158

Within species covariance matrix S.f.i. (Continued).

	LHOM	LMOH	LEBR	LROH	LBOP	LMBO	LWOP	LORL	LOCL	LAPD	LMDD
I ENR											
I ENR											
I ENR											
I UHL											
I LHL											
I LHL											
I BDE											
I DDE											
I HHL											
I HHS											
I HHA	.00317										
I HNA	621E-7	.00153									
I ENR	621E-6	505E-6									
I ROH	418E-7	735E-6	.00174								
I NOP	681E-6	166E-6	799E-6	.00101	.00385						
I MDO	183E-6	111E-6	945E-6	471E-6	.00225						
I EBP	256E-7	426E-6	720E-6	971E-6	774E-6						
I ORL	149E-6	167E-7	116E-6	207E-6	-.0001	.00249					
I OCL	461E-6	-.0002	546E-6	-.0002	133E-7	-.0007	-.84E-6	.00332			
I AFD	671E-6	424E-6	964E-6	300E-6	494E-6	.00168	406E-6	559E-6	-.0003	.00283	
I MD	.00142	212E-7	.00119	760E-7	.00107	183E-6	510E-6	865E-6	.00117	.00128	.00597
I APS	.00103	265E-6	.00104	614E-6	820E-6	.00133	998E-6	556E-6	.00202	.00202	.00289
I SPS	.00115	394E-6	.00116	169E-6	318E-6	-.0014	442E-6	824E-6	.00143	.00305	
I VID	365E-6	626E-6	717E-6	693E-6	730E-6	115E-6	713E-6	488E-6	152E-6	654E-6	673E-6
I HUD	272E-6	686E-6	673E-6	594E-6	684E-6	-.0003	615E-6	478E-6	137E-6	599E-6	811E-6
I LAPL	680E-6	408E-6	571E-6	789E-6	.00132	428E-6	350E-6	186E-6	462E-6	.00134	
I AFM	506E-6	435E-6	474E-6	837E-6	.00106	481E-7	631E-6	382E-6	149E-6	553E-6	885E-6
I CFM	.00127	713E-6	0.0014	703E-6	.00158	.00127	514E-6	-.0003	.00218	.00268	
I MLM	.00228	376E-6	.00112	503E-6	.00122	.00123	426E-6	-.63E-7	.00191	.00271	
I CFL	615E-6	-.0003	634E-6	-.0006	-.0009	-.0009	-.0006	443E-6	.00146	.00192	
I SHL	663E-6	874E-6	929E-6	747E-6	.00101	459E-6	862E-6	501E-6	628E-6	856E-6	818E-6
I SHB	730E-6	1499E-6	660E-6	526E-6	831E-7	737E-6	423E-6	492E-6	-.36E-6	822E-6	943E-6
I SLS	839E-6	482E-6	603E-6	340E-6	416E-7	186E-6	257E-6	298E-6	-.17E-6	704E-6	990E-6
I LHL	.00114	839E-6	973E-6	.00109	0.0022	.00285	819E-6	-.0008	448E-6	.00131	548E-6
I LSL	353E-6	538E-6	707E-6	247E-6	560E-6	-.0005	358E-6	281E-6	.00106	192E-6	664E-6
I GCD	-25E-6	688E-6	694E-6	518E-6	359E-6	375E-6	193E-6	709E-6	130E-6	731E-6	693E-6
I GCN	-59E-6	.00109	.00109	776E-6	.00171	.00204	758E-6	-.0004	-.0003	643E-6	455E-6
I GIL	713E-6	767E-6	937E-6	913E-6	419E-6	397E-6	716E-6	760E-6	-.43E-6	.00109	884E-6
I WPL	813E-6	703E-7	637E-6	316E-6	619E-6	610E-6	149E-6	649E-6	299E-6	757E-6	883E-6
I LEB	27E-6	238E-6	485E-6	631E-6	928E-6	-.0004	295E-6	395E-6	527E-6	121E-6	724E-6

Within species covariance matrix S.f.i. (Continued).

	LAPS	LMLS	LVID	LHND	LAPL	LAPH	LAPN	LMHL	LCFL	LSML	LSMB
I PHE											
I PHF											
I PHH											
I PHL											
I PHI											
I PHJ											
I PHK											
I PHM											
I PHN											
I PHO											
I PHP											
I PHQ											
I PHR											
I PHS											
I PHT											
I PHU											
I PHV											
I PHW											
I PHX											
I PHY											
I PHZ											
I PIH											
I PII	.00353										
I PIS	.00223	0.0054									
I LIVD	830E-6	966E-6	.00116								
I LIHD	694E-6	.00127	.00114	.00146							
I LAPL	911E-6	907E-6	758E-6	906E-6	.00192						
I LAFL	870E-6	813E-6	904E-6	.00118		.00129					
I APFN	.00216	.00255	0.0012	.00118							
I LPHH	n.0025	.00302	949E-6	873E-6	.00132	.00105	.00506				
I LCIL	.00141	.00188	480E-7	339E-6	861E-6	372E-6	.00114	.00517	.00909		
I SML	819E-6	.00136	756E-6	925E-6	909E-6	916E-6	.00104	571E-6	.00106	.00329	
I SHD	928E-6	944E-6	536E-6	487E-6	672E-6	610E-6	954E-6	.00102	890E-6	.00116	.00197
I SLG	951E-6	955E-6	504E-6	337E-6	691E-6	612E-6	565E-6	952E-6	972E-6	.00103	.00166
I LSH	810E-6	.00126	409E-6	453E-6	.00122	0.0012	781E-6	.00164	.00159	.00364	.00185
I LSL	285E-6	887E-6	395E-6	490E-6	451E-6	367E-6	468E-6	965E-6	.00238	396E-6	
I CGD	835E-6	627E-6	590E-6	573E-6	681E-6	538E-6	557E-6	418E-6	478E-7	.00147	718E-6
I CGH	489E-6	.0006	927E-6	999E-6	950E-6	683E-6	.00181	0.0011	.0018	766E-6	827E-7
I GILL	.00104	.00108	886E-6	935E-6	992E-6	818E-6	980E-6	.00105	0.0011	.00212	.00198
I UPL	886E-6	815E-6	326E-6	316E-6	339E-6	416E-6	855E-6	817E-6	.00107	842E-6	949E-6
I LEB	385E-6	650E-6	569E-6	709E-6	923E-6	767E-6	589E-6	690E-6	318E-6	981E-6	147E-6
I LCS	.00137	303E-6	891E-6	515E-6	818E-6	990E-6	.00213	.00138	.0014	904E-6	775E-6
I PCS	.00102	716E-6	282E-6	118E-6	376E-6	157E-6	.00141	.00117	678E-6	426E-6	591E-6

Within species covariance matrix S.f.i. (Continued).

	LSLS	LSSL	LISL	LGCB	LGCH	LGIL	LUPL	LFEB	LLCS	LMCS
LSLS										
LSSL	.00165									
LISL	0.0015	.01082								
LGCB	369E-6	.00109	.00378							
LGCH	661E-6	800E-6	962E-6	.00257						
LGIL	115E-6	1100E-6	.00109	806E-6	.00474					
LUPL	.00161	.00236	.00107	0.0012	598E-6	.00303				
LFEB	853E-6	.00107	481E-6	236E-6	167E-6	.00111	.00141			
LLCS	377E-6	.00108	776E-6	361E-6	758E-6	680E-6	431E-6	.00129		
LMCS	804E-6	.00234	919E-6	389E-6	.00334	0.0012	436E-6	732E-6	0.01	
	191E-6	428E-6	813E-6	177E-7	.00123	805E-6	879E-6	365E-6	.00281	.00304

APPENDIX C
DEFINITION OF MEASUREMENTS

The following 43 measurements were preselected for their ability to isolate morphological complexes and to illustrate aspects of functional anatomy. Following the name of each variable is a three letter code, a compiled definition of the measurement and the references used to define the measurement:

1. Scapula maximum length: (SML) The direct line distance from the most superior point of the cranial angle to the most inferior point on the caudal angle (Bass, 1971:94; Hrdlicka, 1952:170; Montagu, 1960:68; Olivier, 1969:219).
2. Scapula maximum breadth: (SMB) Measured from the middle of the dorsal border of the glenoid fossa to the spinal axis on the vertebral border (Bass, 1971:95; Hrdlicka, 1952; Montagu, 1960:70).
3. Scapula length of the spine: (SLS) Taken from the end of the spinous axis on the vertebral border of the most lateral point of the acromion process (Bass, 1971).
4. Scapula length of the supra-spinous line: (SSL) Taken from the end of the spinous axis on the vertebral border to the top of the anterior angle (Bass, 1971).
5. Scapula length of the infra-spinous line: (ISL) Measured from the end of the spinous axis on the vertebral border to the tip of the inferior angle (Bass, 1971).
6. Scapula glenoid cavity breadth: (GCB) Taken at a point just below the constriction of the ventral border. Measured across the breadth of the glenoid cavity from the ventral to the dorsal margin (McHenry and Corrucini, 1978).

7. Scapula glenoid cavity height: (GCH) Measured from the superior to the inferior margin of the glenoid cavity, being aware that the measurement is taken perpendicular to number 6 above (McHenry and Corrucini, 1978).
8. Scapula mid glenoid to inferior angle length: (GIL) Measured from the middle of the glenoid cavity to the inferior angle (Ingalls, 1924).
9. Humerus maximum length: (HML) The direct distance from the most superior point on the head of the humerus to the most inferior point on the trochlea (Bass, 1971: 114; Hrdlicka, 1952:168, Olivier, 1969:226).
10. Humerus breadth of the upper epiphysis: (BUE) The widest distance across the upper epiphysis, making sure to include the greater tubercle (McHenry and Corrucini, 1978).
11. Humerus maximum diameter of midshaft: (MDS) Taken at the exact mid-length. The maximum diameter of the midshaft (Bass, 1971:115; Hrdlicka, 1952:168).
12. Humerus minimum diameter of the midshaft: (MDM) The least diameter taken at right angle to number 11 above (Bass, 1971:115).
13. Humerus maximum diameter of the head: (MDH) The direct distance between the most superior and inferior points on the border of the articular surface (Bass, 1971: 115).
14. Humerus epicondylar breadth: (EBR) The distance of the most laterally protruding point on the lateral epicondyle from the corresponding projection of the medial condyle on the distal edge (McHenry and Corrucini, 1978).
15. Humerus least circumference of the shaft: (LCS) Taken at the second third of the shaft, distal to the deltoid tuberosity (Bass, 1971:115).
16. Ulna maximum length: (UML) The distance between the most superior point on the olecranon process and the most inferior point on the styloid process (Bass, 1971: 130; Hrdlicka, 1952:169; Olivier, 1969:235).

17. Ulna maximum breadth of the olecranon process: (BOP) Taken from the medial and lateral margins of the olecranon process' articular surface at its greatest breadth (McHenry and Corrucini, 1978)
18. Ulna minimum breadth of the olecranon process: (MBO) Measured from the medial and lateral margins of the olecranon process' articular surface where the constriction on the medial margin becomes apparent (Zobeck, 1983:131).
19. Ulna maximum width of the olecranon process: (WOP) Measured in an antero-posterior direction from the anterior-most portion of the olecranon process to the posterior most portion (McHenry and Corrucini, 1978).
20. Ulna olecranon process to radial notch length (ORL) From the most anterior projecting point on the olecranon process to the most inferior most margin of the radial notch (Zobeck, 1983:131).
21. Ulna olecranon process to coronoid process length: (OCL) Taken from the most anterior projecting point on the olecranon process to the radial most margin of the coronoid process (McHenry and Corrucini, 1978).
22. Ulna physiological length: (UPL) Taken from the two measuring points being the deepest point in the longitudinal ridge running across the floor of the semilunar notch and the deepest point of the distal surface of the head, not including the groove between it and the styloid process (Bass, 1971:130; Olivier, 1969:235).
23. Radius maximum length: (RML) The maximum length from the head to the tip of the styloid process (Bass, 1971:124; Hrdlicka, 1952:169; Olivier, 1969:235).
24. Radius maximum diameter of the head: (RDH) Measured from a point on the edge of the articular surface of the bone across to the opposite side. The head is rotated until a maximum distance is achieved (Trotter and Gleser, 1952).
25. Radius maximum circumference of the shaft: (MCS) Measured at a point just superior to the radial tuberosity (Zobeck, 1983:131).

26. Femur maximum length: (FML) The distance from the most superior point on the head of the femur to the most distal point point on the distal condyles (Bass, 1971:168; Trotter and Gleser, 1952:473; Olivier, 1969:260).
27. Femur trochanteric length: (FTL) The greatest distance between the most superior point of the greatest trochanter and the external (lateral) condyle (Zobeck, 1983:130).
28. Femur subtrochanteric anterior-posterior diameter: (APD) The antero-posterior diameter of the proximal end of the diaphysis measured perpendicular to the transverse diameter. Taken on the shaft just below the lesser trochanter (Bass, 1971:169; Montagu, 1960:70; Olivier, 1969:263).
29. Femur subtrochanteric medial-lateral diameter: (MLD) The transverse diameter of the proximal portion of the diaphysis at the point of its greatest lateral expansion. Measured perpendicular to number 28 above (Bass, 1971:169; Montagu, 1960:70; Olivier, 1969:263).
30. Femur anterior-posterior diameter of the midshaft: (APS) The distance between the two lateral surfaces measured at approximately the midpoint of the diaphysis. Taken at the perpendicular to the ventral surface (Bass, 1971:169).
31. Femur medio-lateral diameter of the midshaft: (MLS) The distance of the two lateral margins of the femur from one another, measured perpendicular (right angle) to number 30 above (Bass, 1971:169).
32. Femur vertical head diameter: (VHD) The greatest vertical diameter in the vertical plane which passes through the axis of the neck (Zobeck, 1983:132).
33. Femur horizontal diameter of the head: (HHD) The maximum diameter of the femur head, measured at a right angle to number 32 above (Bass, 1971:168; Montagu, 1960:70).
34. Femur anterior-posterior diameter of the lateral condyle: (APL) The projected distance between the most posterior point on the lateral condyle and lip of the patellar surface taken perpendicular to the axis of the femur shaft (Montagu, 1960).

35. Femur anterior-posterior diameter of the medial condyle: (APM) The projected distance between the most posterior point on the medial condyle and lip of the patellar surface taken perpendicular to the axis of the femur shaft (Montagu, 1960).
36. Femur epicondylar breadth: (FEB) Measured over the most outstanding points on the epicondyles, parallel to the infracondylar plane (Zobeck, 1983:133).
37. Tibia maximum length: (TML) The distance from the superior articular surface of the lateral condyle of the tibia to the tip of the medial malleolus (Bass, 1971:187; Montagu, 1960:72; Trotter and Gleser, 1952: 473).
38. Tibia maximum breadth of the proximal epiphysis: (BPE) The maximum distance between the two most laterally projecting point on the medial lateral condyles of the proximal epiphysis (McHenry and Corrucini, 1978).
39. Tibia maximum breadth of the distal epiphysis: (BDE) The maximum distance between the two most lateral points on the medial malleolus and the lateral surface of the distal epiphysis. Taken between the fibular articular surface and the medial surface of the medial malleolus (McHenry and Corrucini, 1978).
40. Tibia anterior-posterior diameter at the nutrient foramen (APN) The distance between the anterior crest and the posterior surface at the level of the nutrient foramen (Bass, 1971:187).
41. Tibia medial-lateral diameter at the nutrient foramen: (MLM) Maximum transverse diameter at a right angle to number 41 above (Bass, 1971:187).
42. Tibia position of the nutrient foramen: (CFL) Measured from the top of the lateral intercondylid eminence to the most distal point of the foramen (Zobeck, 1983: 132).
43. Fibula maximum length: (BML) The maximum distance between the most superior point on the fibular head and the most inferior point on the lateral malleolus (Bass, 1971:187).

VITA

Anthony Benjamin Falsetti was born in Kansas City, Missouri on November 12, 1961. He attended primary school in Columbia, Missouri. Anthony and his family, in the summer of 1973, then moved to Knoxville, Tennessee where he attended secondary school in that city and graduated from Bearden Senior High School in 1980. He entered The University of Missouri, Columbia, Missouri the following fall and remained for one year. In the fall of 1981 he returned to Knoxville and continued his undergraduate work at The University of Tennessee, receiving his B.A. in Anthropology in March 1984.

Anthony entered graduate school at The University of Tennessee in the Spring Quarter of 1984 and began study toward the Master of Arts degree. Anthony is married to the former Kristin A. Reese of Knoxville, Tennessee.

He is a member of the American Association of Physical Anthropologists.