

SEX DETERMINATION BY DISCRIMINANT FUNCTION ANALYSIS OF NATIVE
AMERICAN CRANIA FROM FLORIDA AND GEORGIA

By

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To my grandmother,
Sarah Napps, she loved me for who I was,
no matter what. She supported me in
in every way she could, no matter what.
She saw the best in me, and was proud of me, no matter what.
I strive to live up to her image of me, and her pride in me.

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LIST OF ABBREVIATIONS

AUB, au-au	Biauricular breadth
B.P.	Radiocarbon years before present, with present defined as the year 1950.
BBH, ba-b	Basion bregma height
BNL, ba-n	Cranial base length
BPL, ba pr	Basion prosthion length
DFA	Discriminant function analysis.
DKB, d-d	Interorbital breadth
DKB, d-d	Interorbital breadth
EKB, ec-ec	Biorbital breadth
EKB, ec-ec	Biorbital breadth
FOB	Foramen magnum breadth
FOL, ba-o	Foramen magnum length
FRC, n-b	Frontal chord
GOL, g-op	Maximum cranial length
MAB, ecm-ecm	Maxillo-alveolar breadth external palate breadth
MAL, pr-alv	Maxillo-alveolar length, external palate length
MDHA	Average mastoid height
MDHL	Left mastoid height
MDHR	Right mastoid height
MNI	Minimum Number of Individuals
NLB, al-al	Nasal breadth
NLH, n-ns	Nasal height
OBB, d-ec	Orbital breadth
OBH	Orbital height

OCC, l-o	Occipital chord
p	P-value, the probability of getting a value at least as extreme as the observed value by chance alone.
PAC, b-l	Parietal chord
UFBR, fmt-fmt	Upper facial breadth
UFHT, n-pr	Upper facial height
WFB, ft-ft	Minimum frontal breadth
XCB, eu-eu	Maximum cranial breadth
ZYB, zy-zy	Bizygomatic breadth

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The goal of this research is to determine if the accuracy of discriminant function analysis for sex determination could be improved by using local or regional populations, and by better variable selection. In archaeological contexts, skeletons are usually all that remains of the actual people who once lived there. Information about the sex of those individuals is fundamental to the study of demographics, sex roles, and life ways of past cultures. Determining an individual's sex is also fundamental to personal identification of skeletal remains from modern contexts, whether from a mass disaster or an unmarked grave.

There are several techniques available for determining sex from skeletal remains, and each technique has its place. Discriminant function analysis is valuable in sex determination because it requires relatively little training to use effectively and it serves as an objective check to other methods. The cranium is a reliable indicator of sex and is often the best indicator of sex when other parts of the skeleton have been damaged, destroyed, or separated from the cranium.

Previous research assumed that discriminant functions for sex determination developed for one population could easily be used for all populations, with little regard for the skeletal variation between populations. This work tests the hypothesis that sex determination by discriminant function analysis of the crania for Florida and Georgia Native American remains

from archaeological contexts is more accurate when the functions are developed using remains from those populations than functions developed from other populations.

Cranial measurements and sex identification data are collected from skeletal collections housed at the Florida Museum of Natural History at the University of Florida, and the Smithsonian Institution's National Museum of Natural History. The sample includes 46 individuals from ten Native American archaeological sites in Florida and Georgia, ranging from the Middle Archaic Period to the Spanish contact era.

This research finds that existing discriminant function formulas disproportionately misclassify skeletons from the Florida and Georgia unless the formula is adjusted for that population. Additionally, existing formulas require measurements that are rarely preserved or that do not contribute to identifying sex. New discriminant function formulas based on skeletons from Florida and Georgia are only nominally more accurate than existing formulas, but it is no more difficult to produce new formulas than to adjust existing formulas. Creating new formulas also provides the opportunity to select variables that are more often preserved in archaeological contexts and that also clearly contribute to identifying the sex individuals. This research finds that existing formulas are reliable only if the sectioning point is adjusted for the study population.

CHAPTER 1 INTRODUCTION

Sex identification has long been an important part of skeletal analysis in the archaeological setting. Accurate sex estimations are basic to studies of past adaptations of humans to new environments and demographic histories. Archaeologists may use sex information to establish demographic patterns, study the affect of sex on status within a particular archaeological culture, or to examine migration patterns (Buikstra and Ubelaker 1994:15). Additionally, forensic anthropologists may use this information to help identify an individual in a medico-legal context.

Methods for sex identification have evolved from visual methods to include metric methods based on univariate and multivariate statistical analysis, particularly discriminant function analysis. Using visual methods to determine sex, an osteologist may examine the overall size of the subject, the size of the mastoid process, the shape of the frontal bone, or the gonial angle of the mandible. The determination of sex using visual method relies primarily on the experience and judgment of the osteologist. Using these methods, osteologists typically achieve an accuracy of 80% to 90% (Giles and Elliot 1962). Metric methods use various measurements of the skeleton, many of which attempt to capture aspects used in visual methods (David Hunt, personal communication 2006). In univariate analysis, a single measurement of an individual is compared to the distribution of measurements from a sample of known sex specimens to arrive at the likely sex of the individual. Using only one measurement, however, does not account for differences in shape of a skeletal element between males and females, and for any single measurement there is considerable overlap between the range of variation for males and females. Multivariate methods use multiple measurements which can capture the shape of a skeletal element and minimize the amount of overlap between males and females. Discriminant function analysis is a multivariate method designed for this problem.

Discriminant function analysis was developed to solve the problem of predicting group membership based on one or more interval variables. The goal of discriminant function analysis is to minimize misclassification by maximizing between group differences, or minimizing group overlap. Discriminant function analysis is also used to determine which variables best discriminate between groups, and in what ways groups differ. How well a function performs is usually reported in terms of how many cases would be correctly assigned to their groups using the discriminant functions (Manly 1994).

One widely used discriminant function for sex determination is calculated by Giles and Elliot (1963) based on data collected from the Terry and Hamann-Todd skeletal collections. The Terry and Hamann-Todd collections are comprised of skeletal remains collected from cadavers used by medical school anatomy classes during the late nineteenth and mid-twentieth centuries (Hunt and Albanese 2005). The problems presented by a medical school cadaver sample include possible effects of the inherent socio-economic bias on skeletal morphology. The Terry and Hamann-Todd skeletal collections are biased, with older individuals and males overrepresented compared to the population as a whole, and they do not include Native Americans. For studying the sex differences in skeletons, however, such collections are essential because the sex of each individual is positively known from written records (Giles and Elliot 1963:56). The sample Giles and Elliot used to calculate their discriminant functions did not include any native Americans, but the formulas are tested on three series of American Indian crania from Indian Knoll ($N \geq 344$), Pecos Pueblo ($N \geq 110$), and Florida ($N \geq 217$). These materials are analyzed by Snow (1948; Johnson and Snow 1961), Hooton (1930), and Hrdlička (1940) respectively. “On the whole the discriminant functions described [by Giles and Elliot 1963], assign the correct sex, assuming that the original estimations are correct, with the same order of magnitude as they do

for the black and white sample. For the Florida Indians, however, this is true only when the sectioning point is based on mean values of these same Indians.” (Giles and Elliot 1963:66-67).

Can the accuracy of sex determination by discriminant function analysis be improved over Giles and Elliot's results by deriving new formulas based on regional populations? This hypothesis is tested using skeletal remains recovered from archaeological sites in Florida and Georgia.

CHAPTER 2 SEX DETERMINATION

Introduction

This chapter describes the various visual, univariate, and multivariate metric methods used in sex determination using cranial and post-cranial skeletal remains. Estimating sex from a skeleton relies on sexual dimorphism, the morphological differences between men and women. Men tend to possess a larger body size when compared to females. Female morphology must allow for both bipedal locomotion and giving birth to relatively large-headed babies when compared to other primates. With a complete adult skeleton, and particularly a complete pelvis, a physical anthropologist should be able to correctly assign sex with nearly perfect accuracy. Additionally, the anthropologist should be able to recognize ambiguous cases where sex identification is less certain. If the complete skeleton is not available, accuracy depends largely on what bony elements are available and if the skeleton can be linked to a specific population. If the skeleton is fragmented or from a sub-adult, then determining the sex is more difficult and less reliable than with a complete adult skeleton. Methods of sex determination are either visual or metric, and apply to the crania and post-cranial skeleton. For the best results, the forensic anthropologist should use all available data.

Visual Methods

Visual methods for estimating sex from the skeleton make use of size differences between men and women or morphological differences related to childbirth in women. Sexing methods that rely on morphological differences in the pelvis related to childbirth are the most accurate. The method for sexing the skeleton by the pubic bone developed by Phenice (1969) is the most accurate method known for determining the sex of an individual from the skeleton (White 1991).

Phenice (1969) identifies three indicators of sex in the pubic bone: the ventral arch, the subpubic concavity, and the medial aspect of the ischiopubic ramus.

The ventral arch is a slightly elevated ridge of bone that sweeps inferiorly and laterally across the ventral surface of the pubis, merging with medial border of the ischiopubic ramus. The ventral arch is evaluated by orienting the pubis so that its rough ventral surface faces the observer, who looks down along the plane of the pubic symphysis surface. The ventral arch, when present, sets off the inferior, medial corner of the pubic bone in ventral view. The ventral arch is present only in females. Male pubic bones may have elevated ridges in this area, but these do not take the wide, evenly arching path of the female's ventral arch or set off the lower medial quadrant of the pubis.

The subpubic concavity is a concave curve on the medial edge of the ischiopubic ramus displayed in female *os coxae*. The female ischiopubic ramus is concave, while male edges are straight or very slightly concave. The subpubic concavity is evaluated by turning the pubis over, orienting it so that its smooth, convex dorsal surface faces the observer, who is once again sighting along the midline. From this position it is possible to observe the medial edge of the ischiopubic ramus. For females, the edge of the ramus is concave in this view. Males do not show the dramatic concavity here. Male edges are straight or very slightly concave. (If the bone is in good shape, and there is no danger of damage, another method for evaluating the subpubic concavity is to lay the ischiopubic ramus on a flat surface. If it can be rocked, it indicates a male, if it cannot be rocked, it indicates a female).

To evaluate the medial aspect of the ischiopubic ramus, the observer turns the pubis 90°, orienting the symphysis surface so that the observer is looking directly perpendicular to it. From this position it is possible to observe the ischiopubic ramus in the region immediately inferior to

the symphysis. This medial aspect of the ischiopubic ramus displays a sharp edge in females. In males the surface is fairly flat, broad, and blunt.

In the Phenice method, some criteria may not obviously sex the specimen, so those criteria should be discarded. If there is some ambiguity concerning one or two of the criteria, there is usually one of the remaining criteria that clearly indicate the subject's sex. Accuracy of sexing based on this method ranges from 96 to 100% (White 1991:325).

Because of its position in childbirth, the pelvis includes many other characteristics that can be used to visually estimate sex. Compared to the male, the female pelvis is broader, has a wider sciatic notch, and normally includes a pre-auricular sulcus (a groove between the auricular area and the sciatic notch). It has a smaller acetabulum (the socket that holds the head of the femur), a longer pubic bone, and a wider subpubic angle. The sacrum is shorter and broader, and the obturator foramen smaller and triangular in females. Compared to females, the male pelvis may be heavier and more robust, and the auricular area tends to be flatter. The pre-auricular sulcus seldom occurs in males, but if present in males, it is shallower than in females. The obturator foramen is larger and ovoid in males. Evaluation of these criteria individually yields accuracies from 83 to 94%. In combination, accuracies range from 95 to 98% (Rogers and Saunders 1994:1050-1051).

After the pelvis, the next best indicator of sex is the cranium. Estimation of sex is based on the generalization that the male is more robust and has muscle attachment points that are larger and rougher. Male muscle attachment points are especially pronounced on the occipital bone, where they may form a nuchal crest. Males also have larger mastoid processes, more prominent supraorbital ridges, and the posterior end of the zygomatic process extends farther as a crest. The

upper edges of the eye orbits are blunt, and frontal sinuses are larger in males. On the mandible, the male chin is squarer, and the gonial angle is more acute.

Compared to the male, the female cranium is smaller, smoother and more gracile. In the female mandible, the chin is more rounded and pointed, and the gonial angle is more oblique. The smaller size of the female cranium is evident in a smaller palate, and smaller teeth. Females also display frontal and parietal bossing into adulthood; the upper edges of the eye orbits are sharp.

Evaluation of these characteristics depends not only on the experience of the osteologist, but also on matching the specimen to a genetically and temporally close comparative population (Bass 1995; White 1991). Using the crania, an experienced osteologist should be able to make a sex determination that is 80-90% accurate. Buikstra and Ubelaker (1994:16-20) provide a scoring system for several of these visual traits.

For the remainder of the skeleton, males tend to be larger than females, with long bones that are longer, heavier, and have larger attachment areas for muscles, including the linea aspera, crests, tuberosities and impressions (Brothwell 1981, Stewart 1948). These criteria are useful if a related skeletal series is available, but for isolated or fragmentary remains this is only useful if the bone is at the extreme end of the range, either 'very male' or 'very female.'

Metric Methods

While visual methods can estimate sex quickly and accurately, their evaluation is subjective and requires experience with sexing techniques and the relevant population. Metric procedures are based on quantifying the same criteria used in visual sexing. A metric procedure could be better if the observer is not familiar with visual techniques or the relevant population. Additionally, metric procedures serve as an objective check to visual methods and can strengthen the position of the osteologist as expert witness in a courtroom (Stewart 1979). The simplest

metric methods use a single measurement, and compare it to a distribution of that measurement from a collection of known sex individuals. A sectioning point is placed such that males and females are equally likely to be classified correctly, and misclassifications are minimized. The sectioning points are usually arrived at by discriminant function analysis. Sectioning points for several different long bones are given by Bass (1995), and an exhaustive list of discriminant function studies to determine sex and their accuracies can be found in Rathbun and Buikstra (1984:212-216). There are a host of discriminant function tests based on cranial and post-cranial measurements.

Giles and Elliot (1963) provide one of the best established discriminant functions for sex determination using the skull. From combinations of nine cranial measurements a total of 21 discriminant functions are described to indicate sex in whites, blacks and whites and blacks taken together. The measurements are:

Glabella-occipital length: The maximum length of the skull, from the most anterior point of the frontal in the midline to the most distant point on the occiput in the midline.

Maximum width: The greatest breadth of the cranium perpendicular to the median sagittal plane, avoiding the supra-mastoid crest.

Basion-bregma height: Cranial height measured from basion to bregma.

Maximum diameter bi-zygomatic: The maximum width between the lateral surfaces of the zygomatic arches measured perpendicular to the median sagittal plane.

Basion-nasion: The direct distance from basion to nasion.

Basion-prosthion: The direct distance from basion to the most anterior point on the maxilla in the median sagittal plane.

Nasion breadth: The maximum breadth of the nasal aperture perpendicular to nasal height.

Palate-external breadth: The maximum breadth of the palate taken on the outside of the alveolar borders.

Opisthion-forehead length: The maximum distance from opisthion (the midpoint on the posterior border of the foramen magnum) to the forehead in the midline.

Mastoid length: The length of the mastoid measured perpendicular to the plane determined by the lower borders of the orbits and the upper borders of the auditory meatus (Frankfort plane).

Functions 1, 2, and 3 use 8 of the 9 measurements, are the most accurate for each group, and use the same measurements from each group. The sectioning point is halfway between the

mean score for males and the mean score for females. A score above the sectioning point is designated male; one below is designated female.

Table 2-1. Coefficients for discriminant functions 1,2, and 3 from Giles and Elliot 1963 used to assign sex based on a white sample, a black sample, and a combined black and white sample.

Measurements	Whites (Function 1)	Blacks (Function 2)	Combined (Function 3)
Glabello-Occipital Length (GOL)	3.107	9.222	6.083
Maximum Width (XCB)	-4.643	7.000	-1.000
Basion-Bregma height (BBH)	5.786	1.000	9.500
Max Diameter Bi-zygomatic (ZYB)	14.821	31.111	28.250
Basion-Prosthion (BPL)	1.000	5.889	2.250
Prosthion-Nasion Height (UFHT)	2.714	20.222	9.917
Palate--External breadth (MAB)	-5.179	-30.556	-19.167
Mastoid Length (MDH)	6.071	47.111	25.417
Sectioning Points	2676.39	8171.53	6237.95
Male mean	2779.66	8487.56	6466.17
Female Mean	2573.12	7855.50	6009.72
Sample Accuracy (Percent correct)	86.1%	84.6%	86.0%
Expected Accuracy	86.6%	87.6%	86.4%

A large variety of metric methods using the post-cranial skeleton are available in Krogman and Iscan (1986) and Bass (1995). These are commonly used in forensic anthropology. Several methods were developed for fragmentary remains that focus on bioarchaeology collections. Using Bioarchaeology collections has the advantage of using the population of interest to develop criteria, but in most cases the true sex of the individuals in the study is unknown. Therefore, true accuracy cannot be determined, only how consistent the method is with other, established methods.

Several studies have been focused on identifying sex from fragmentary remains. Using a discriminant function based on only the midshaft femoral circumference of prehistoric skeletons from Ohio, Black (1978) recorded an accuracy of 85%. Using the same measurement, DiBennardo and Taylor (1979) developed and tested discriminant functions on black and white femora of known sex and achieved an accuracy of 82%. Using various combinations of three

measurements, Taylor and DiBennardo (1982) recorded accuracies between 80 and 85% for white femora.

Dittrick and Suchey (1986) minimize the problem of unknown sex by using only skeletons with the pubic bone and applying the Phenice method. Suchey had established an accuracy of 99% in sex determination by using a blind test on pubic bone pairs from modern autopsies of individuals over age 16. In tests on prehistoric central California skeletal remains, they achieved accuracies of about 90% using linear discriminant function analysis of measurements from the ends of the long bones. Interestingly, functions based on multiple measurements did not produce results much better than the best functions using single measurements.

One of the limitations of discriminant function analysis is that the functions should only be used on skeletons that come from the same population as the one used in development of the function. Otherwise, results can be unpredictable. Giles and Elliot (1963) tested their own functions on skeletons from Ireland and on three series of native American skeletons from Indian Knoll in Ohio, Pecos Pueblo, and Florida. The functions correctly sexed 40 of 42 males (95%) and 3 of 8 females (37.5%) of the Irish skeletons. Giles and Elliot dismiss the poor female result and take this as evidence that their formula can be used across populations. A better interpretation is that the formula disproportionately misclassifies females as male. For the Native American samples, good results are achieved only after altering the sectioning point. Although it has been used in the literature, altering sectioning points is not a practical solution to using discriminant functions across populations (Calcagno 1981; Henke 1977). Kajonoja (1966) found that the Giles and Elliot functions had an accuracy of only 65% on Finnish crania. It is interesting to note that the functions developed by Giles and Elliot (1963) for the combined sample of blacks and whites worked about as well on blacks and whites separately as it did on

the combination of both groups. This suggests that functions developed on a wider population can achieve good results across that population's constituent groups. (See Henke 1977 for a more detailed discussion of using discriminant function analysis across populations.)

The methods and criteria discussed above are only applicable to adult remains. A skeleton may be considered an adult if all long bone epiphyses are fused or if the third molars have erupted. For sub-adults, if age can be established from dental development, then sex can be estimated from long bone lengths (see Bass 1995). Other sexing techniques for sub-adults use sex differences in pelvic measurements (see Krogman and Iscan 1986:200-208).

CHAPTER 3 DISCRIMINANT FUNCTION ANALYSIS

Discriminant function analysis (DFA) has been used extensively to determine sex by archaeologists and forensic anthropologists (e.g. Giles and Elliot 1963; Black 1978; DiBennardo and Taylor 1979, 1982, 1983; Dittrick and Suchey 1986). The results are comparable to those of traditional methods, but requires far less training and experience. This section describes the goals and capabilities of discriminant function analysis, some of the methods for calculating discriminant functions, and introduces research using discriminant function analysis in sex determination.

Discriminant function analysis addresses the problem of how well it is possible to separate two or more groups of individuals using multiple combinations of weighted variables. DFA requires classes that are predetermined, such as male or female. The object is not to create classes or populations that divide heterogeneous material. With two groups, there are two specific errors one can make: mistaking a member of one group for being from the other. For example, misclassifying (1) a male as a female, or (2) a female as a male. Both types of mistakes should occur at an equal rate, and there should be as few mistakes as possible. Finally, each subject must be assigned to one population or the other so that “Unknown” is not an option (Kendall 1957).

There are several approaches, including Canonical discriminant functions, Mahalanobis distances and logistic regression. These methods are described below, followed by the advantages and disadvantages of DFA and by a literature review of DFA used in sex determination.

Canonical Discriminant Functions

Canonical discriminant functions determine a combination of variables that separate the groups as well as possible. Fisher (1936) introduced a simple way to choose the coefficients for a linear function that maximizes the F-ratio of a one-way analysis of variance for two groups, which is the ratio of between group variance to within group variance. Specifically, his paper deals with the discrimination of *Iris setosa* and *Iris versicolor*¹, two species found growing together in the same colony. His variables are measurements of sepal length, sepal width, petal length, and petal width. Most of the literature cites Fisher as the originator of discriminant function analysis, but he cites "Mr. E.S. Martin" and "Miss Mildred Barnard" for applying the principle to sex differences in the mandible and a secular trend in cranial measurements, respectively.

The approach involves finding coefficients for a linear combination of n variables:

$$Z = a + b_1x_1 + b_2x_2 \dots b_nx_n$$

where Z is the discriminant function score, a is a constant, b_1 through b_n are discriminant function coefficients, and x_1 through x_n are independent variables, which maximizes the F-ratio of Z in a one-way analysis of variance for the two groups. Finding the coefficients of the canonical discriminant functions is an eigenvalue problem. Details on the computation of DFA coefficients can be found in Manly (1994).

Discriminant function analysis has uses other than classifying individuals. Discriminant function coefficients can also be used to evaluate how groups differ (Manly 1994:114). Howells (1989) used discriminant functions as a form of data reduction, similar to the way others have used principle components analysis, but that use is not common in the literature.

¹ The article is primarily concerned with the discrimination of *I setosa* and *I versicolor*, but Fisher extends his analysis to test the hypothesis that *I virginica* is a hybrid of *I setosa* and *I versicolor*.

Among the most widely cited uses of canonical discriminant function analysis in anthropology come from Giles and Elliot, who used the technique for the estimation of sex (1963; Giles 1964) and race (Giles and Elliot 1962). For these studies, Giles and Elliot used measurements of Native American remains from the Indian Knoll, KY site originally published by Snow (1948), while black and white subjects came from the Terry and Todd Collections. Their use of discriminant functions for estimation of sex from the crania is discussed in detail in the chapter on sex estimation. In their calculations, Giles and Elliot used formula from Kendall (1957), which are equivalent to those presented by Fisher (1936). Using Black and White individuals from the same sample, Giles and Elliot (1963) developed discriminant functions for sex using nine cranial measurements in different combinations to form 21 discriminant functions for sex determination. An accuracy of 82-89% is attained with the Black and White material. This compares favorably with the 77-87% accuracy expected from visual sex estimation using the cranium alone.

Multiple Discriminant Functions

When canonical discriminant analysis is used, it may be possible to determine several linear combinations of variables for separating groups where there are multiple groups and variables. The number of functions available is either the number of variables or one less than the number of groups, whichever is smaller. All functions maximize the F-ratio subject to the condition that they are uncorrelated with previous functions within groups. The canonical discriminant functions are, therefore, linear combinations of the original variables chosen such that the first function reflects group differences as much as possible, and subsequent functions capture as much as possible of group differences not displayed by previous functions. Group assignment is then accomplished by calculating the distances to group means (Manly 1994:108-

110). While this method is useful for analyzing group differences, it is computationally difficult for the end user to assign individuals to groups.

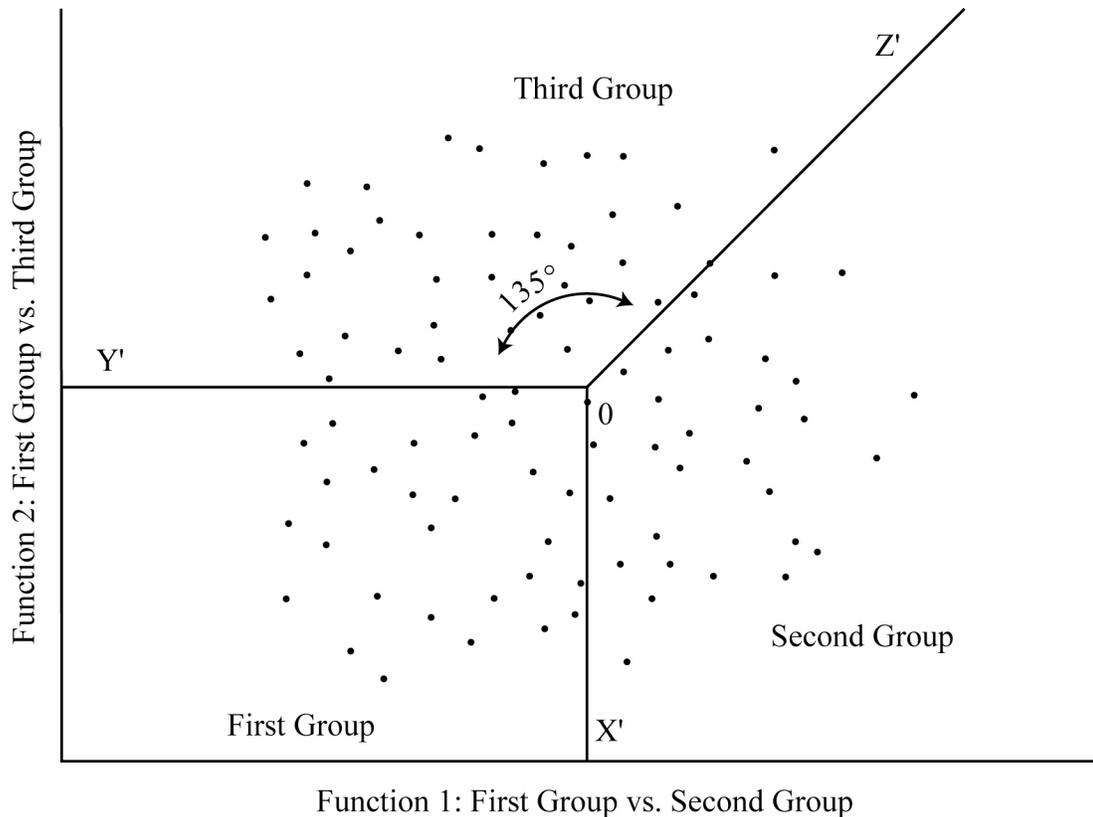


Figure 3-1 Discriminant Function Analysis with three groups using the graphic device proposed by Rao. Function 1 is plotted on the X-axis, Function 2 is plotted on the Y-axis. Thin rods X' , Y' , and Z' are placed to minimize errors (Adapted from Rao 1952; Giles and Elliot 1962).

A different method is used by Giles and Elliot (1962) to estimate race. Giles and Elliot (1962) use a pair of canonical discriminant function formulas for the placement of a skull into white, black, or Native American categories: One formula for black vs. white, and the other for white vs. Native American. The two functions are then plotted, with the black-white function on one axis, and the white and Native American function on the other. To place individuals into one of the three groups, Giles and Elliot use a geometrical device described by Rao (1952:327),

which is not common in the literature (see fig. 3-1; Giles and Elliot 1962). The Giles and Elliot functions correctly identified race for 82.6% of males 88.1% of females (Giles and Elliot 1962).

Tests of Significance

Various tests of significance are available for evaluating the difference between the mean values for any pair of groups, overall differences between the means of several groups, and if the mean of a discriminant function differs from group to group. See Harris (1985) for a discussion of the difficulties surrounding these tests.

Prior Probabilities

Some computer programs can allow for prior probabilities of group membership. This could be useful in sex determination if reliable data can be generated for the proportion of male and female skeletons recovered from a particular environment, whether due to taphonomy, demographics, or other causes. Care should be taken that assignment of prior probabilities reflects actual or known proportions (e.g. number of males and females in a population) and not any form of prior bias.

Stepwise Discriminant Function Analysis

Stepwise discriminant function analysis simply applies a stepwise selection to the variables included in a discriminant function analysis. Variables are added to the discriminant functions, one at a time, until adding additional variables does not give significantly better discrimination. Several authors have used stepwise discriminant function analysis in estimating sex from skeletal measurements. Holman and Bennett (1991) use the procedure built into SAS (STEPDISC) on the bones of the arm and wrist with good results. Taylor and DiBennardo (1982), DiBennardo and Taylor (1983), and Iscan and Miller-Shaivitz (1984) each use the procedure built into SPSS for the femur, femur and pelvis, and tibia, respectively, with good results.

Mahalanobis Distance

The Mahalanobis distance (D^2) is a measure of distance that takes into account correlations between variables. For classification purposes, Mahalanobis distance can be used to measure the distance of individuals to group centers and each individual can be allocated to the group to which it is closest. If x_1, x_2, \dots, x_p are the values of variables X_1, X_2, \dots, X_p for the individual, with corresponding population mean values of $\mu_1, \mu_2, \dots, \mu_p$, then:

$$D^2 = \sum_{r=1}^p \sum_{s=1}^p (x_r - \mu_r) v^{rs} (x_s - \mu_s)$$

where v^{rs} is the element in the r th row and s th column of the inverse of the covariance matrix for the p variables (Manly 1994:63).

Assumptions

Both canonical and Mahalanobis distance methods are based on two assumptions. The first is that the within-group covariance matrix is the same for all groups. The second is that the data is normally distributed within groups. The second assumption is important for the validity of tests of significance.

Logistic Regression

A different approach to discrimination between two groups uses logistic regression. Logistic regression is a variation of multiple linear regression where the dependent variable is assigned as either 1 or 0, usually used as 'success' or 'failure.' The regression formula then returns a probability of success or failure. Rather than representing success or failure, 1 and 0 can be used to represent groups. When applied to unknown individuals, the regression will return the posterior probability of group membership, with a sectioning point of 0.5. Konigsberg and Hens (1998) use logistic regression in sex estimation on measurements of the crania. They reported

good results, but found the method “cumbersome.” They preferred a probit model that used categorical independent variables.

Conclusion

On the whole, the accuracy of DFA in identifying sex is no more accurate than visual methods when used by a trained osteologist. The advantage is that someone who is not an osteologist, with brief instructions in measuring, can perform discriminant function sexing quickly and objectively. This group includes medical examiners and archeologists who have had some training in osteology, but who may be inexperienced or ‘rusty’ (Krogman 1962; Birkby 1966; Giles 1970). For the trained osteologist and forensic anthropologist, discriminant function analysis can be used as an objective check to visual methods and adds weight to expert testimony (Snow 1979).

Discriminant function analysis has two critical limitations when used for sex estimation of skeletal remains. The first is the need for all measurements used in the function to be observable. The second is that the functions can only be used on individuals who come from the population from which the function was developed.

The first problem is fairly straightforward, as is its solution. A discriminant function score cannot be calculated if an observation is missing. One solution is to generate multiple functions using different combinations of measurements. Another solution is to generate functions using skeletal elements that are robust, and therefore likely to be preserved. This approach was taken by Black [femur] (1978); DiBennardo and Taylor [femur] (1982) ; Taylor and DiBennardo [stepwise-femur] (1982); Iscan and Miller-Shaivitz [tibia] (1984); Dittrick and Suchey [femur and humerus] (1986).

The problem of using functions across populations is more difficult. Some authors have suggested moving the sectioning point by various methods, including using the mid-point

between the means of the sexes (Giles and Elliot 1963), finding the sectioning point graphically from the bimodal distribution of the scores (Giles and Elliot 1963), or placing the sectioning point at the grand mean of the function scores (Henke 1977). Henke (1977) tested each of these methods, and also used the unmodified functions. Henke concluded that only the first two methods are practical. Calcagno (1981) found that moving the sectioning point by any method was not a practical solution to the problem. Placing the sectioning point mid-way between the means of the sexes requires that one first know the sex of the skeletons. The graphic method is not practical because the distribution of discriminant scores is multimodal, and not bimodal. Finally, placing the sectioning point at the grand mean of the discriminant scores assumes that the sexes are equally represented in the sample, which is particularly unlikely to be true in archaeological series (Henke 1977). Henke's conclusion seems to be that discriminant functions developed for one group can be used on another, but the sectioning point has to be adjusted. Birkby (1966) tested the Discriminant Functions developed by Giles and Elliot for race and sex (1962; 1963). His goal was to determine (1) if discriminant function analysis is applicable in the assessment of race and sex in human identification and (2) the reliability of such techniques. He found Indian crania are often misclassified for race and sex. Birkby concludes that the Indian Knoll sample used by Giles and Elliot (1962, 1963) is not representative of Native Americans as a whole. Therefore, the functions based on those data are not applicable in the identification of race and sex in human identification, either forensic or archaeological.

Snow et al. (1979) performed another test of the Giles and Elliot discriminant functions using forensic cases. The discriminant function for sex determination attained an accuracy that was not significantly different from Giles and Elliot. With no significant difference in accuracy between the sexes.

For race, Native Americans are misclassified at a significantly higher rate than non-Native Americans (83% correct for black and white combined vs. 14% correct for Native Americans). Snow et al. conclude that the Giles and Elliot functions “provide a useful tool for the determination of sex and race of unidentified crania submitted for forensic science examination.” The functions, however, did not perform well among Native American subjects. “It thus appears that the 5000 year old Indian Knoll crania used by Giles and Elliot in developing their functions do not adequately represent the entire U.S. category of Indian” (Snow et al 1979:459).

The advantages of discriminant function analysis in physical anthropology are that it is relatively easy to apply, allowing sex and race estimations by those with little training in osteology, and that it is an objective indicator of race and sex, especially for isolated remains. The weaknesses include needing to develop functions on the populations from which the subject comes, and the need to be able to make all of the measurements called for in the discriminant function, which is not always possible in fragmentary remains typically found in archaeological sites. Functions developed with fragmentary remains in mind help avoid the problem of missing measurements.

CHAPTER 4 ARCHAEOLOGICAL CONTEXT

Introduction

This chapter provides a general cultural history of the southeast, introduces the archaeological sites that provide the skeletal materials for this study. It places those sites geographically, temporally and within the framework of the area's cultural history.

Environmental Setting

Human occupation in what is now Florida and Georgia began about 13,000 B.P.² during the end of the Pleistocene epoch. From the start of human occupation until about 7000 B.P., Florida and Georgia were undergoing tremendous environmental change. The environment gradually went from cold and dry at the end of the Pleistocene, to the warm and humid modern climate. That change in temperature was accompanied by higher sea levels, which have reduced Florida to half the land area of what it was when people first entered the state. Along with a warming climate and rising sea levels, many of the plants and animals in Florida and Georgia were supplanted by species better adapted to the changing environment. By 7000 B.P. sea levels reached about the levels where they are today, and the flora and fauna present were essentially the same species present in the region today (Milanich 1994).

The coastal zone of the region, including the Gulf of Mexico and Atlantic coast of Florida and southern Georgia, is characterized by a generally inhospitable beach and foreshore. This area is subject to seasonal exposure to storms and scarce resources. Chains of barrier islands are also found along the eastern coastline of Florida and Georgia containing beach and dune landscapes,

² B.P. stands for years before present based on radiocarbon dating, with present defined as the year 1950. It is an alternative to traditional dates of A.D. and B.C.. B.P. dates can be roughly converted to traditional dates by subtracting 1950, but radiocarbon years are not equivalent to calendar years. For this reason, the dating framework used in the primary reports for each site and region are followed without attempting to impose imprecise conversions.

Live Oak hammock, tidal flats, and estuary habitats. Farther inland, the sandy beaches and dunes give way to broad estuaries, mudflats, and thickly vegetated shores. These areas serve as place for marine and inland species to interact (Milanich and Fairbanks 1978; Williams 2004:13). Inland areas of northern Florida and Georgia with an abundance of fresh water, such as along streams and lakes, are dominated by hardwood hammocks. Hardwood hammocks are dense forests characterized by a broad spectrum of plant communities that provide shelter and food for a vast array of animals (Milanich 1998; Milanich and Fairbanks 1978; Wallace 1978).

Cultural History

Prehistoric occupation of the southeastern United States, or Southeast, is divided into periods and sub-periods that reflect changes in technology, environment, and subsistence. Breaks between periods are often subtle, and changes occur at different times across the region. Archaeological cultures describe specific regional or local units from specific time periods. Periods include Paleoindian, Archaic, Woodland, and Mississippian. The Archaic, Woodland, and Mississippian periods are divided into Early, Middle, and Late sub-periods. The Woodland and Mississippian cultures are comprised of a number of regional cultures.

Paleoindian Period

The initial period of human occupation in North American is termed the Paleoindian period, and is characterized by the occurrence of fluted stone projectile points or knives, such as Clovis, Suwannee, and Simpson points. The best available evidence suggests that during the late Pleistocene bands of highly mobile hunters crossed the Bering land bridge from Siberia into Alaska. The Bering land bridge was exposed during the last glaciation when large amounts of water were locked up in the polar ice caps and ice sheets, resulting in the lowering of global sea levels by about 100 meters. The presence of mid-continent ice sheets appear to have prevented movement of these populations eastward from Alaska until about 13,000 B.C. based on the

distribution of fluted points in the archaeological record. Most of North America appears to have been occupied by 10,000 B.C. (Bense 1994: 38-39; Milanich 1994: 37-40).

The general consensus is that the Paleoindian life ways were based on the hunting of large game animals and the gathering of a variety of plant foods. Paleoindians were highly mobile, and were probably organized into bands with widely ranging patterns of movement and inter-group interaction (Doran 2002:49,50; Bense 1994;Griffin 1979:51). Because of their mobility, the traditional expectation has been that they should exhibit a basic biological similarity over a wide geographical area (Key 1983:8; Meiklejohn 1972). Preliminary results from Ross, Ubelaker and Falsetti (2002), however, indicate that Native Americans are much more biologically heterogeneous than previously thought.

During the Paleoindian period, the climate was cooler and dryer than today, but with reduced seasonal variation. Sea levels were as much as 100 meters below current levels (Clausen et al 1979; Widmer 1988). In Florida, this resulted in more land being exposed, lower water tables and few sources of surface water. This scarcity of surface water is thought to be a determining factor in Paleoindians settlement patterns in Florida. It is also thought that many sites that were along the coast during the Paleoindian period have been inundated by rising sea levels (Bullen 1958; Ruppé 1980). Most Paleoindian sites found to date consist of little more than limited scatters of lithic debitage (Edwards 1954; Waller 1969).

The human skeletal remains of fewer than 100 individuals from the Paleoindian period have been recovered from all of North America. In Florida, Paleoindian sites with human remains include Little Salt Spring, Warm Mineral Springs, and Cutler Ridge, although the material at Little Salt Spring cannot be incontrovertibly placed within the Paleoindian occupation (Doran 2002).

The Archaic Period

The Archaic Period describes is differentiated from the earlier Paleoindian period on the basis of stylistic differences in point types, the appearance of new artifacts types, and apparent changes in economic orientation (Anderson and Sassaman 2004). The change in material culture from Paleoindian to Archaic coincided with a change to a warmer, less arid climate. As the temperature increased, the glaciers retreated and sea levels rose. Because of these environmental changes many species that had previously thrived in the Southeast went extinct or disappeared from the region. Changes in flora and fauna led to changes in subsistence patterns and material culture.

The regional chronology for the Archaic period in the Southeast was established by correlating changes in diagnostic artifacts from excavations at deeply stratified sites such as Ice House Bottoms in Tennessee, Russell Cave in Alabama, Indian Knoll in Kentucky, and the Hardaway and Doerschuk sites in North Carolina (Stoltman 2004). The Archaic is traditionally divided into Early, Middle, and Late Archaic phases.

Early Archaic

The Early Archaic can be seen as a transition from the Paleoindian period to the Middle Archaic. Population increased throughout the Archaic, and people were shifting from nomadic hunting to somewhat more sedentary lifestyles near coastal and riverine settings (Milanich 1994). The shift in subsistence strategies coincided with a period of transition to warmer, less arid conditions. Projectile points transition from lanceolate forms present during the Paleoindian period to stemmed, side- and corner-notched, and hafted forms with bifurcated bases (Anderson and Sassaman 2004; Milanich 1994:63). The Early Archaic appears to reflect a continuation of the Paleoindian hunting and gathering lifestyle with increased regional specialization. Early

Archaic sites have been found at a number of locations in Georgia (Wauchope 1966) and Florida (Milanich 1994), many near permanent water sources.

Because of the rapidity of post-glacial sea level changes, the complex estuary systems that would eventually become dominant resource procurement areas for many coastal populations had not stabilized. Stable, productive estuary systems were not present until after 3,000 B.C. Sea level rise caused ground water levels to rise increasing the amount of surface water available (Widmer 1988; Watts 1975; Doran 2002:50). The increase in surface water made new locations suitable for occupation, allowing Archaic peoples to move into new ecotones (Milanich 1994:63). Additionally, “because water sources were large and more numerous, the Early Archaic peoples could sustain larger populations, occupy sites for longer periods, and perform activities that required longer occupation at a specific locale” (Milanich 1994:69). A period of greater aridity returned near the end of the Early Archaic, about 6000 B.C., though less arid than at the end of the Pleistocene.

Middle Archaic

Average annual temperatures during the Middle Archaic were not much different than modern temperatures, but temperature variance was more extreme. Summers were hotter and winters were colder. While lake water levels were lower throughout much of the North American continent, sea and ground water levels were higher in Florida and Georgia (Anderson and Sassaman 2004). During the Middle Archaic period more and larger surface water sources were available in Florida, and increasingly moist conditions appeared after about 4000 B.C. (Milanich 1994:84; Watts 1969, 1971; Watts and Hansen 1988). A gradual change in forest cover occurred with pines and mixed forests replacing oaks. By about 3000 B.C., vegetation and climate become essentially modern, and sea level rise tapered off (Milanich 1994:75, 84).

The Middle Archaic was a time of dramatic cultural change in the Southeast. Middle Archaic peoples occupied new types of locations for the first time and created new types of sites, including freshwater and marine shell middens (Milanich 1994). Ceremonial shell and earthen mound construction were initiated in several areas, long-distance trade networks appeared, and new tool forms were adopted (Anderson and Sassaman 2004:95). Both Early and Middle Archaic peoples in peninsular Florida began using aquatic environments, such as Windover pond, for burial (Milanich 1994:81).

Late Archaic

The beginning of the Late Archaic coincides with the beginning of the late Holocene Period and essentially modern environmental conditions by 3000 B.C. (Milanich 1998; Sassaman and Anderson 2004; Watts and Hansen 1988:310). This period is marked by greater regionalization and cultural diversity as human populations adapted to specific environmental zones. Cultures were no longer faced with the challenge of long-term environmental and climatic fluctuations (Milanich 1994).

During the Late Archaic period, the firing of clay pottery, along with other technological innovations, appeared in Florida. Ceramic vessel technology gradually spread across the southeast, and was adopted by virtually all regional populations by about 650 B.C. “Local variations in pottery technology and style reflect growing diversity of cultural expression. Regional exchange and intergroup ritual at locations of ceremonial earthworks were among the means by which members of different populations interacted” (Anderson and Sassaman 2004:101). More Late Archaic sites are known than sites from any earlier period.

Despite changes in technology, there are few apparent differences between Late Archaic subsistence strategies and earlier periods. Populations in the Southeast continued to expand on the hunting and gathering economies of ancestral populations, with shellfish, fish and other food

resources becoming increasingly important (Milanich 1994:85). With the exception of areas that eventually adopted intensive agriculture, the general subsistence patterns of the late Archaic period continued largely unchanged into the colonial period (Milanich 1994; Sassaman and Anderson 2004). Diminished rates of sea-level rise promoted the establishment of increasingly productive estuarine environments, and maturing floodplain habitat. During this time, evidence of coastal populations in Florida is much more abundant, and Late Archaic shell middens are preserved in many locales (Milanich 1994; Sassaman and Anderson 2004:101). “The panregional spread of mortuary ceremonial institutions and greater use of native cultigens in certain sub-regions mark the end of the period at about 650 B.C.” (Sassaman and Anderson 2004:101).

Woodland and Regional Cultures

The Woodland period follows the Archaic. It is characterized by increasing population and social complexity through time, and limited adoption of horticulture. With more people on the landscape, mobility decreased and local manifestations of the culture emerged. Trade and exchange with regions outside the Southeast occurred to some extent. As groups settled into their local environment and became more sedentary, regional cultures began to emerge. Regional cultures are distinguished by variations in potter styles, projectile point styles, house types, and settlement patterns. Due to the abundance of regional cultures, only the woodland cultures represented in the skeletal sample are detailed here.

The advent of the Woodland period occurs at different times throughout Eastern North America, but began earlier in Florida and Georgia and lasted until the European contact in some areas. After 500 B.C., there is archaeological evidence for occupation of every environment within Florida, including the forested interior uplands of northern Florida (Milanich 1994: 106). After about A.D. 750, there is evidence for more intensive cultivation of plants, including the possible introduction of maize (Milanich 1994: 108).

Kellog

The Kellog culture was concentrated in northwest Georgia Piedmont between about 800 and 200 BC. Kellog settlements include large, year round camps concentrated in narrow flood plains adjacent to streams, and small seasonal camps. Kellog base camps covered about an acre and include abundant artifacts, some sites having middens several feet thick. Seasonal camps are not as common and contain fewer artifacts. Kellog material culture is dominated by fabric marked pottery early in the period, with simple stamp and check stamp pottery more popular later. Stone tools included both stemmed and unstemmed chipped stone points with triangular blades, slate hoes, and biconvex mortars (Bense 1994:135). Kellog culture subsistence strategies were not much different than Archaic strategies of hunting, gathering and fishing, but with perhaps more emphasis on plant foods (Bense 1994:135-136; Hally and Mainfort 2004:266).

Deptford

The Deptford culture was located along the Gulf coast of Florida and the southeast Atlantic coast between 500 BC and AD 100. The Deptford culture area is located between Mobile Bay and Cedar Key along the Gulf coast stretching inland approximately 60 miles, and along the Atlantic coast of South Carolina, Georgia, and northern most Florida extending 30 miles inland. Modest Deptford shell middens found along the coast are located in hardwood hammocks near salt marshes and estuaries, while inland sites are usual located in river valleys. Deptford coastal villages are small and generally contain 5 to 10 houses of either cold weather houses or summer warm weather pavilions. The cold weather houses are around 20 by 30 foot ovals, and the warm weather pavilions are approximately 20 by 13 foot ovals. As might be expected from their choice of site locations, Deptford peoples relied heavily on fish and shellfish gathered from tidal streams and shallow inshore waters, as well as nearby terrestrial resources. Inland sites are small as well and may be special use sites, such as hunting camps (Milanich 2004a:193-194). "In both

the Atlantic and Gulf areas sand burial mounds appear during the Deptford period. By AD 1 some mounds on the Gulf coast contained items thought to be linked to Hopewellian-related beliefs and trade” (Milanich 2004a:194). As the Southeast entered the Middle woodland period, Deptford was succeeded by the Swift Creek culture in most areas.

St. Johns/Malabar

The Saint Johns culture persisted along the Atlantic coast of Florida for around 2,000 years, from the end of the Archaic in 500 BC into the seventeenth century and contact with the Spanish. The Saint Johns region includes two sub-regions, the St. Mary’s zone in the North, and the Indian River Zone in the south. The Indian River Zone is located around Brevard, Indian River, and St. Lucie counties, and with sites found near wetlands of the Saint Johns River Basin, the Indian River, and along barrier islands (Milanich 1994: 249). The culture of the Indian River Zone during the Saint Johns period is identified as the Malabar culture, and is divided into two periods (Rouse 1951). The Malabar I period is approximately contemporaneous with the Saint Johns I period, present from 500BC to 750 AD, while Malabar II is of the same age as the Saint Johns II period, present from 750AD to 1565 AD (Milanich 1994: 247,249-250). Malabar sites can be classified as villages, special use sites, or single use sites. Villages are large, multicomponent sites that exhibit a wide range of artifacts and large middens. Villages are always located near wetlands, and are surrounded by special use sites. Special use sites are smaller multicomponent sites used intermittently for short periods of time. Single use sites were probably used to gather some specific resource, and all that remains are small artifact scatters or a few animal remains (Milanich 1994:251-252). Malabar peoples were foragers, and subsistence patterns were remarkably consistent through both phases, with diets composed of roughly 15% terrestrial resources, such as deer, raccoons, and rabbits, and 80% fish and shellfish. As time passed and water levels changed, the Malabar peoples tended to collect larger fish and a wider

variety of species (Milanich 1994:251,253). The Malabar I pottery assemblages include Saint Johns sponge-spiculate tempered pottery, but are dominated by undecorated pottery tempered with quartz sand. Malabar II pottery is characterized by the appearance of Saint Johns Check Stamped pottery. Analysis of pottery from Malabar sites shows continuity of manufacturing methods through both periods (Cordell in Sigler-Eisenberg et al 1985:118-134; Milanich 1994:250) and a link to Saint Johns pottery (Espenshade 1983; Milanich 1994:250).

Manasota

The Manasota culture found along the central peninsular Gulf coast region coincided with the Deptford and early Weeden Island cultures, lasting from about 500 B.C. to A.D. 700. This region, which surrounds Tampa Bay, extends along the Gulf from Pasco county south to Sarasota County, and stretches inland nearly to the Peace River drainage. Most Manasota village sites are multicomponent shell middens of various sizes found on or near the shore. Some of the coastal shell middens include shell ramps constructed to provide access to the tops. Intensively occupied interior villages with dirt middens have been found in wetland locals (Hemmings 1975; Padgett 1976; Luer et al. 1987; Milanich 1994). Other types of Manasota sites are found away from the coast, in interior pine flatwoods on higher ground near water sources and wetland habitats. These are presumed to be short-term villages and special use camps (Austin and Russo 1989). The evidence from these sites suggests that the Manasota economy was based on fishing, hunting, and shellfish gathering. Most of the Manasota meat diet was derived from aquatic species, including fish, shark, rays, and shellfish. The Manasota peoples also consumed terrestrial species such as deer, canines, rodents, birds, reptiles and amphibians (Milanich 1994). Manasota material culture is dominated by the use of shell tools with some bone tools, but little use of stone tools. Ceramics were limited to plain sand-tempered pottery (Luer and Almy 1979:40-41 in Milanich 1994:222-223).

Wilmington Culture

The Wilmington Culture succeeded the Deptford culture along the coast and coastal plain of Georgia at the end of the Late Woodland period, 500-1150AD. The Wilmington Culture is defined by Wilmington Plain, Wilmington Cord Marked, and Wilmington Brushed ceramics (DePratter 1979; Martinez 1975). The typical Wilmington vessel is decorated with large, parallel individual cord impressions made with a cord wrapped paddle (Caldwell 1952:316). Wilmington culture is thought to have been influenced by the coeval Weeden Island culture in Florida and by Mississippian people in the Piedmont (Milanich 1976). Like other Late Woodland cultures, Wilmington subsistence was based on hunting, fishing and gathering with some horticulture (Wood et al 1986).

Historic Period

The historic period begins with European contact. This happens at different times in different areas, and initially has varying degrees of impact. For the Timucua of Northern Florida and Southern Georgia, contact with Europeans probably begins in 1525 and early 1526 when scout ships that preceded the Lucas Vázquez de Ayllón expedition landed on the northern end of St. Simons Island (Hoffman 1994; Milanich 2004b:225). In 1565 the Spanish began to establish a missions and colony in Florida with their first permanent New World settlement in St. Augustine. From this base they established Roman Catholic Missions along the Atlantic Coast to the Timucua Indians and Guale Indians along the Georgia coast just north of the Timucua. At the time of the Spanish arrival, many of the Guale and Timucua in northern Florida and Georgia were already involved in maize agriculture and readily missionized. By 1620 virtually every Timucuan chiefdom had received Franciscan missions (Milanich 2004b:225). Non-agricultural groups south of the Timucua, such as the Calusa, were not missionized, despite numerous Spanish attempts.

The Timucua and the Guale paid a terrible price for their service to the Spanish crown. The Spanish used the Indians as a labor force to support the Spanish colony. They did supply the Indians with technology to increase maize production, but the demand for maize and labor shifted the native populations from a semi-nomadic hunting, gathering, and farming subsistence base to sedentary intensive maize agriculture. The maize diet led to nutritional deficiencies, especially in lysine, tryptophan and iron. These deficiencies can be seen in the remains of mission Indians in the form of porotic hyperostosis, cribra orbitalia, and enamel hypoplasia. The increased physical stress imposed by the Spanish need for labor can be seen in the form of osteoarthritis. They also experienced increased levels of carious lesions and periosteal reactions due to the increased stresses of mission life. Indian populations under the mission system dropped sharply as a result of working conditions and a series of Old World disease epidemics in 1595, 1612-1617, 1649-1650, and 1655-1656. Population levels were further impacted by slaving raids by the English and their allies from 1660 to 1684 (Milanich 1998). As the Timucua populations declined, the Spanish consolidated the remaining tribes along the Camino Real, giving them access to the Apalachicola and their labor. By the time the Spanish ceded Florida to the English in 1763, the Timucua had dwindled from a pre-contact population of approximately 20,000 in the early sixteenth century to a single adult. Other Indian populations in Florida and Southern Georgia were similarly decimated, and the few remaining survivors were evacuated to Cuba when the Spanish left Florida (Milanich 1994, 2004b; Williams 2004).

CHAPTER 5 SITES

Introduction

Of the ten archaeological sites used in this study, six (Golf Course, Bay Pines, Canaveral, Casey Key, Palmer, and Perico Island) are located along the coast of Florida, and three (Cannon's Point, Taylor Mound, and Couper Field/Indian Field) are located on Saint Simon's Island, Georgia. The tenth site (Garfield) is located in the Piedmont of Georgia. These sites represent to Archaic, Deptford, Weeden Island, and contact periods. These sites date from possibly as early as the Paleoindian through the Contact period. Site numbers and brief descriptions of the location, the archaeological investigation, and the interpretation of each of these sites follow below.

Golf Course (8Br44)

The Golf Course site is located on the north edge of the Melbourne Municipal Golf Course just east of a canal that cuts through the property in Melbourne, Brevard County, Florida. The site was discovered in 1952 by F.B. Loomis of Amherst College, J.W. Gidley of the U.S. National Museum (Smithsonian), and C.P. Singleton, a resident of Melbourne, during a survey of spoil from the nearby canal (Rouse 1951: 153). Loomis and Gidley prevaricated on whether the remains came from the Pleistocene Melbourne bone bed, or from the lower levels of the overlying Holocene Van Valkenburg bed. Aleš Hrdlička argued that the "Melbourne Man" was similar to recent Indians and could not be of great antiquity based on his analysis of the skulls morphology and his own conviction that humans had not entered the New World more than a few thousand years ago (Miller 1950; Wilmsen 1965). After reconstructing and reexamining the skull, Stewart (1946) suggested that it might in fact belong to the Paleoindian period. (Milanich 1994:8; Miller 1950) While the lack of a definitive cultural affiliation is frustrating, this case is

an excellent example of the kind of where the present research will be of the greatest benefit, namely in gathering information about isolated remains with uncertain affiliation.

Bay Pines (8Pi64)

The Bay Pines site is located in Pinellas County, Florida on Boca Ciega Bay, just west of St. Petersburg. The site consists of a shell ridge oriented on a north-south axis, parallel to the coast of Boca Ciega Bay. The north end of the ridge is near a freshwater lagoon, and two smaller ridges are present perpendicular to the shore, one in the middle, and one at the south end termed "shell ridge A." Shell ridge A was excavated by members of the Suncoast Archaeological Society in 1971 in a salvage operation prior to the construction of a nursing home. Ten burials are identified in a cemetery and fragmentary remains of at least 14 other individuals are found scattered throughout what was probably a burial mound. The remains of all 24 individuals are currently housed at the Florida Museum of Natural History. The site is thought to be multi-component with occupations from the Deptford period through the early Weeden Island period. A reanalysis of faunal remains associated with the site and stable isotope analysis of the skeletons suggest a diet heavy in fish from the nearby Gulf of Mexico and included turtle, mammal, bird, crab and possibly maize (Gallagher and Warren, 1975; Kelly, Tykot and Milanich 2006).

Canaveral (8Br85)

The Canaveral site is located on Cape Canaveral in Brevard County, in the Indian River area of Florida's Atlantic coast. . Dr. George Woodbury excavated burial mounds on Cape Canaveral from 1933-1934 as part of the Civil Works Administration relief archaeological program affiliated with the Bureau of American Ethnology, Smithsonian Institution during the Great Depression (Milanich 1994:9-10). The site consists of several burial mounds, including the Burns Mound and Fuller Mounds A, B, and D. The Burns Mound (8Br85) is a burial mound built

on top of a shell midden. The burial mound was composed of a lower sandy layer and an upper layer composed of “a thick laminated deposit which contained ... charcoal, pot sherds, shells, etc.” (Woodbury n.d.). Woodbury recovered 31 burials from the lower zone and 21 from the upper zone; all are primary burials with their heads oriented toward the center of the mound in a spoke pattern. All of the upper zone burials are extended while some from the lower zone are flexed or semi-flexed (Willey 1954:81). All but one of the burials are adults with approximately equal numbers of males and females. The Burns Mound is dated to the Malabar II period based on ceramic types, although a pendant of European silver indicates the mound was used after European contact.

The excavation at Fuller Mound A recovered in a sample of 96 complete skeletons. All but twelve are adults, with slightly more females than males. Almost all of the burials are oriented in the spoke pattern with their heads toward the center of the mound. Most are primary extended burials lying on the back, although a few are semi-flexed. A few may have been secondary burials. Iron and metal tools and glass beads of European manufacture are present (Stirling 1935:386). Based on the ceramics and the quantity of European goods, Rouse (1951:197) suggested that the mound dates from the 17th century.

Fuller Mound B contained the remains of about 20 individuals disarticulated and mixed in a single secondary burial at the center of the mound. Two primary burials are also found away from the center with their feet pointing toward the center of the mound (Stirling 1935:387). Rouse (1951:197) dates the mound to the Malabar I' period based on the ceramics and the lack of European artifacts.

Fuller Mound D consisted of 16 primary extended burials in the spoke pattern oriented with heads toward the center of the mound. Five of the individuals are infants, and there are

more adult males than females. A few glass beads are present suggesting that the mound dates from the 17th century, the same as Fuller Mound A (Stirling 1935:387).

Casey Key (8So17)

The Casey Key site lies on Casey Key, a Gulf coast barrier island located about three miles south of Osprey, in Sarasota County, Florida. The site was known to residents of the area long before it was recorded by archaeologists and has never been systematically excavated. The site is near the Palmer site, discussed below, and is thought to have been roughly contemporaneous with it, although it is not tightly dated due to a dearth of diagnostic artifacts. The limited pottery assemblage indicates it is from the Manasota-Weedon Island culture dating from ca. A.D. 250-750. Casey Key included a village and a burial mound that is thought to have contained over 200 burials but most of these are collected by local residents or sold by high school students. A few skeletons were donated to the Florida Museum of Natural History in the 1950s and 1960s by Hilton Leech, who attempted to salvage some data from the mound before it was completely destroyed (Bullen and Bullen 1976:47-48).

Palmer Burial Mound (8So2a)

The Palmer Site is a complex of sites located near Osprey, in Sarasota County, on Little Sarasota Bay on the Florida Gulf Coast. The site was the subject of a number of scientific excavations. The first formal excavations by Ripley Bullen between 1959 and 1962 are the most extensive and only ones to include the burial mound (Bullen and Bullen 1976). Those excavations recorded five sites: Hill Cottage Midden, dating to the Archaic period; Shell Ridge, dating to the Middle Woodland period; Shell Midden, dating from Middle Woodland through Mississippian periods; the North Creek Area middens; and Palmer Burial Mound. A survey of the Palmer tract performed in 1974 uncovered four additional sites, including another burial mound (Miller 1974). Limited investigations were performed in 1979 and 1980 prior to the

establishment of the Spanish Oaks historical site. The Shell Ridge area was excavated in 1991 under the direction of Corbett Torrence, George Luer, and Marion Almy, and detailed zooarchaeological analyses were conducted (Hutchinson 2004; see Almy and Luer 1993; Kozuch 1998; Quitmyer 1998).

Bullen and Bullen (1976:35) describe Palmer Mound as “a very unassuming, dome-shaped, sand mound rising 4 feet above the surrounding land.” Despite its modest appearance, it is actually one of the largest systematically excavated burial mounds in the southeast, with over 400 individuals recovered. The mound was used primarily between A.D. 500 and 800, during the Manasota period (Bullen and Bullen 1976; Hutchinson 2004:43-59; Williams 2004). Faunal analysis indicates that fish and shellfish dominated the diet, with little consumption of terrestrial animals, but some use of terrestrial plants.

Perico Island (8Ma6)

The Perico Island site is located on the western edge of Perico Island in Manatee County, Florida, west of Bradenton, and between Sarasota and Tampa Bays. The site is composed of large and small shell middens, a burial mound, and a cemetery area. The site was excavated by Dr. M.T. Newman in 1933-34 as a relief project. Newman recovered 185 flexed burials from the burial mound, and 43 primary flexed burials from the cemetery (Willey 1949:176,180). Willey (1949) initially categorized the site as a local variant of the Glades culture (Willey 1949;1998:192), but it is now considered part of the Manasota culture (see Milanich 1994; Luer and Almy 1982).

St. Simons Island, Georgia

Remains are used from three sites located on the northern end of St. Simon’s Island, Martinez B-C, Taylor Mound, and Couper Field/Indian Field. All were excavated as part of the St Simons Island Archaeological Project operated by the University of Florida between 1972 and

1975. All three locations are on Cannon's Point at the northern end of the island. Wallace (1975) used ceramic and mortuary analysis to examine the relationship between these sites. He found that the sites are from a single, contemporaneous group of Guale Indians, but represent different hierarchical groups within the culture. That conclusion will not be challenged here.

Martinez B-C is located at the tip of Cannon's Point near the Hampton River. The test pit was excavated there in 1974 and initially two burials were recovered. A third burial discovered adjacent to the test pit was recovered in 1975. The individuals include one infant and two adult males, and all are primary extended burials. This location is thought to be part of a primary living area. Based on associated ceramics, the burials are thought to be from the Wilmington Period (Martinez 1975:56-58).

Taylor Mound is a Historic period (ca. A.D.1600-1650) ceremonial mound with associated burials. While some historic artifacts are associated with the mound, it does not appear to have been heavily impacted by European contact (Wallace 1975:39-78; Zahler 1976:2). Eleven burials were recovered from this location, The sex of one skeleton could not be identified because it was too fragmented and too young. A second was excluded from analysis because its stratigraphic affiliation was uncertain (Wallace 1975:44). The remaining nine individuals included seven females and two males. Prior to formal excavation, thirteen burials were excavated by local residents, but information for these individuals was not recorded.

Couper Field and Indian Field are the northern and southern parts, respectively, of the same village, and is part of the same sociocultural population as Taylor Mound, but represents different levels of the social hierarchy. Couper Field lies immediately south of the remains of the antebellum Couper Mansion. Although the area had been heavily plowed the majority of burials are undisturbed. There are 16 interments containing 18 individuals, including one infant, ten

females and seven males (Wallace 1975:141-144). Indian Field was the location of a large ceremonial pavilion in which were interred six burials that contained the disturbed, fragmented, and mixed remains of 22 individuals. Remains of at least 13 of these are recovered from a single interment (Zahler 1976: 8).

Garfield Site (9BR57)

The Garfield site is the remains of a village located on the confluence of the Etowah River and Macedonia Slough near Kingston, Bartow County, in northwestern Georgia. Portions of the site were first excavated by two amateur archaeologists from Decatur, Georgia, James Chapman and Richard Criscoe during the 1960s. Eighteen burials are recovered from what appeared to be abandoned storage pits. Those remains were transferred to the Florida Museum of Natural History in 1974 with other collections they had excavated. Jerald T. Milanich tested the site in 1972 while he was a post-doctoral fellow at the Smithsonian Institution. He recovered an additional four burials, including two adults, one infant, and one cremation. An additional fragment of human bone was identified among animal bone excavated from midden deposits. Artifacts recovered from the site indicate it belongs to the Kellogg culture dating to 600 B.C. to A.D. 100, a date supported by two radiocarbon assays (1855±70 B.P. and 2350±60 B.P.) from charcoal obtained by Milanich (Jerald T. Milanich personal communication 2007; Milanich 1975).

Milanich also recovered a large quantity of floral and faunal remains, ceramics, and lithic artifacts. As a group they suggest an occupation from early spring into late summer or early fall. While it seems likely that some maize gardening was carried out toward the end of the site's period of occupation, wild foods, especially nuts and other plant products, fish and a variety of mammals, provided most of the diet (Milanich 1975).

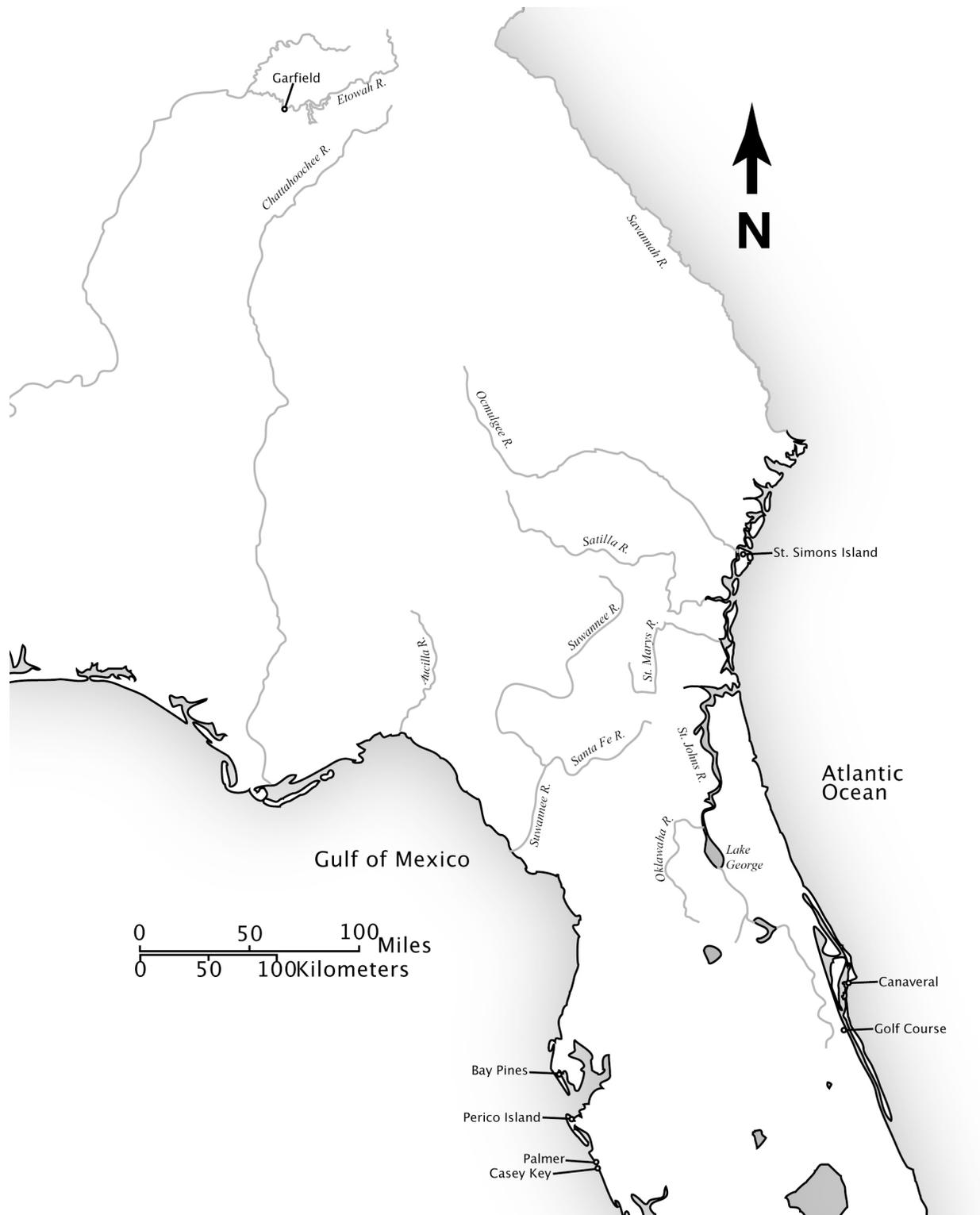


Figure 5-1 Locator map of sites used in this study and major rivers.

CHAPTER 6 METHODS AND MATERIALS

Introduction

This section describes sampling methods and the criteria used for selecting skeletal materials for measurement. It also describes the skeletal materials used for this study and the methods used in determining the sex of each skeleton. Finally, it describes the procedures used in data collection, including measurements taken and their description, and the software and methods used in calculating the discriminant functions.

Sampling

In terms of research design, the ideal approach is to take a simple random sample or random block sample from all pre-contact Native American skeletons excavated from Florida or Georgia archaeological sites, and sex them using the pubic bone. Unfortunately, this ideal is not practical. The remains of Florida and Georgia Native Americans are housed in several institutions around the country, and not all are readily accessible. Of the accessible remains, not all have measurable crania. Of those, few have an intact pubic bone, and none are of known sex. Therefore, it is necessary to draw the sample from those remains that can provide the needed data. The best practical method is to use all of the available remains that have a measurable cranium, and which can be reliably sexed. This ‘total sample’ approach is likely to introduce bias into the sample. For example, individuals who are robust, buried in shell middens, or from more recent populations are likely to be over represented.

Determination of Sex

The sex of the specimens is determined by using visual assessment of the crania and postcrania described in chapter 2. The Phenice (1969) method is used in conjunction with other postcranial indicators, such as the sciatic notch and pre-auricular sulcus, and with cranial

indicators. In sexing skeletons, the heaviest weight is given to the Phenice method of sexing the pubic bone because of its high accuracy, followed by other features of the pelvis and postcrania. Cranial indicators are given the least weight, and sexing by crania alone is avoided.

Materials

The samples used in this study come from a total of ten sites. Samples from Canaveral, Perico Island, and Ballard Estates are housed at the Smithsonian Institution's National Museum of Natural History. Samples from Garfield Site, Couper Field, Taylor Mound, Cannon's Point, Palmer, Casey Key, and Bay Pines are from the Collections of the Anthropology Division of the Florida Museum of Natural History. Measurements are taken from a total of 46 individuals. Because some individuals are incomplete, not all measurements could be taken for every individual, so not all individuals are included in each stage of the analysis.

Data are collected from one complete adult male recovered from the Garfield site. The complete set of 25 cranial measurements is recorded. The postcrania, including the pubic bone is missing, so sexing is accomplished using visual evaluation the crania.

Data are collected from nine individuals recovered from Couper Field, five males and four females. Two of the four females are excluded from further analysis because they lacked a measurable pubic bone and have fragmentary crania. The remaining two females are sexed with using visual analysis of the crania and postcrania. Two males have an observable pubic bone. The remaining three males are sexed using visual analysis of the crania.

Data are collected from seven individuals recovered from Taylor mound, including four males, two females and one individual of unidentified sex. One male and one female are excluded from further analysis because they lacked postcranial remains including the pubic bone and have fragmentary crania. Two males are sexed using the pubic bone, although their crania are fragmentary, and with only seven and 14 observable measurements. The remaining male and

female are sexed using a combination of cranial and visual analysis of the postcrania, but did not include the pubic bone. The individual of unidentified sex is missing postcranial sex indicators, and the cranium is fragmentary.

Data are collected from one male recovered from Cannon's Point. This individual has a fragmentary cranium, allowing observation of 9 of 25 cranial measurements; but possesses a relatively complete postcrania that included the pubic bone. This individual is sexed using cranial and postcranial visual methods, including observation of the pubic bone.

Data are collected from nineteen individuals recovered from Canaveral, including three females and 16 males. All three females and 14 males have crania that are complete or nearly complete, and have relatively complete postcrania including the pubic bone. All 17 are sexed using a combination of cranial and postcranial visual methods, including observation of the pubic bone. The remaining two male crania and postcrania are nearly complete, but lack an observable pubic bone. These two individuals are sexed using a combination of cranial and postcranial visual methods, excluding observation of the pubic bone.

Data are collected from four individuals recovered from from Perico Island, including two males and two females. All four individuals are complete, allowing observation of all 25 cranial measurements and the pubic bone. All are sexed using a combination of cranial and postcranial visual methods, including observation of the pubic bone.

Data are collected from two individuals recovered from the Palmer site, including one male and one female. The female is nearly complete, allowing observation 24 of 25 cranial measurements and the pubic bone. This individual is sexed using a combination of cranial and postcranial visual methods, including observations of the pubic bone. The second individual is a fragmentary male, allowing observation of only 7 of 25 cranial measurements, and is missing the

pubic bone. This individual is sexed using a combination of cranial and postcranial visual methods, excluding the pubic bone.

Data are collected from one female cranium recovered from Casey Key. This cranium is nearly complete, allowing observation of 22 cranial measurements. The postcrania including the pubic bone is missing. This individual is sexed using visual analysis of the cranium.

Data are collected from one malerecovered from Bay Pines. This individual is nearly complete, allowing observation of all 25 cranial measurements but not the pubic bone. This individual is sexed using a combination of cranial and postcranial visual methods, excluding the pubic bone.

Data are collected from one male recovered from Ballard Estates. This individual is nearly complete, allowing observation of 23 of 25 cranial measurements but not the pubic bone. This individual is sexed using a combination of cranial and postcranial visual methods, excluding the pubic bone.

Cranial Measurement Definitions

Giles and Elliot Measurements

Ten measurements are taken from Giles and Elliot (1962, 1963) following their descriptions (Table 6-1). Other sources are used to clarify descriptions and measurement techniques where Giles and Elliot are unclear, particularly Bass (1971, 1995), Howells (1973), Buikstra and Ubelaker (1994), and FORDISC 2.0 materials (Ousley and Jantz 1996).

The remaining measurements (Table 6-2) are not included in the Giles and Elliot (1962) study, but are used in more recent research by Bass (1995), Howells (1973), Buikstra and Ubelaker (1994), and FORDISC 2.0 materials (Ousley and Jantz 1996). The descriptions and techniques primarily follow Ousley and Jantz (1996).

Table 6-1. Measurements used by Giles and Elliot, the measurement's modern equivalent, common symbols, Giles and Elliot descriptions, and references used. Complete measurement descriptions and techniques are listed in appendix A.

Giles and Elliot measurement	Modern equivalent	Symbols	Description	References
Glabello-occipital length	Maximum cranial length	g-op, GOL	The distance of glabella (g) from opisthocranium (op) in the mid sagittal plane measured in a straight line.	Bass 1971:62; Howells 1973:170; Martin 1956:453 ; Olivier 1969:128.
Maximum width	Maximum cranial breadth	eu-eu, XCB	The maximum width of the skull perpendicular to the mid-sagittal plane.	Bass 1971:62; Howells 1973:172; Hrdlička 1952:140; Martin 1956:455 ; Montagu 1960:44.
Basion-bregma height	Basion bregma height	ba-b, BBH	The direct distance from the lowest point on the anterior margin of the foramen magnum, basion (ba), to bregma (b).	Bass 1971:62; Howells 1966:6; Martin 1956:459 ; Olivier 1969:129.
Maximum diameter bi-zygomatic	Bizygomatic breadth	zy-zy, ZYB	The direct distance between each zygion (zy), located at the most lateral points of the zygomatic arches.	Bass 1971:67; Martin 1956:476 .
Basion-nasion	Cranial base length	ba-n, BNL	The direct distance from nasion (n) to basion (ba).	Howells 1966:6; Martin 1956:455
Basion-prosthion	Basion prosthion length	ba pr, BPL	The direct distance from basion (ba) to prosthion (pr).	Martin 1956:474.
Nasion breadth	Nasal breadth	al-al, NLB	The maximum breadth of the nasal aperture.	Bass 1971:68; Howells 1973:176; Martin 1956:479; Montagu 1960:50; Olivier 1969:153.

Table 6-1. Continued

Giles and Elliot measurement	Modern equivalent	Symbols	Description	References
Palate-external breadth	Maxillo-alveolar breadth, external palate breadth	ecm-ecm, MAB	The maximum breadth across the alveolar borders of the maxilla measured at its widest point, between each ectomolare (ecm).	Bass 1971:70; Howells 1973:176; Martin 1956:480; Montagu 1960:51.
Mastoid length	Mastoid length	MDH	The projection of the mastoid process below, and perpendicular to, the eye ear (Frankfort Horizontal) plane in the vertical plane.	Howells 1966:6; 1973:176.
Prosthion-Nasion Height	Upper facial height	n-pr	The direct distance from nasion (n) to prosthion (pr).	Howells 1966:6; Hrdlička 1952:143; Martin 1956:476.

Table 6-2. Measurements not used by Giles and Elliot, common symbols, measurement descriptions, and sources of the measurements. Complete measurement descriptions and techniques are listed in appendix A along with a sample data collection sheet.

Measurement	Symbol	Description	References
Biorbital breadth	ec-ec, EKB	The direct distance from one ectoconchion (ec) to the other.	Howells 1973:178
Interorbital breadth	d-d, DKB	The direct distance between right and left dacryon (d).	Martin 1956:477.
Maxillo-alveolar length, external palate length	pr-alv, MAL	The direct distance from prosthion (pr) to alveolon (alv).	Bass 1971:70; Hrdlička 1952:146 147; Martin 1956:480.
Biauricular breadth	au-au, ALB	The least exterior breadth across the roots of the zygomatic processes.	Howells 1973:173
Foramen magnum length	ba-o, FOL	The direct distance of basion (ba) from opisthion (o).	Martin 1956:455

Table 6-2. Continued

Measurement	Symbol	Description	References
Minimum frontal breadth	ft-ft, WFB	The direct distance between the two frontotemporale (ft).	Bass 1971:67; Hrdlička 1952:142; Martin 1956:457; Olivier 1969:151.
Foramen magnum breadth	FOB	The distance between the lateral margins of the Foramen magnum at the point of greatest lateral curvature.	Martin 1956:459
Upper facial breadth	fmt-fmt	The direct distance between each frontomolare temporale (fmt). This measurement differs from Howells' FMB in that the lateral most points on the suture are used rather than the most anterior points.	Martin 1956:475.
Nasal height	n-ns, NLH	The direct distance from nasion (n) to nasospinale (ns).	Bass 1971:68; Howells 1966:6; Martin 1956:479; Olivier 1969:153
Orbital breadth	d-ec, OBB	The laterally sloping distance from dacryon (d) to ectoconchion (ec).	Martin 1956:477 478; Howells 1973:175
Orbital height	OBH	The direct distance between the superior and inferior orbital margins.	Bass 1971:69; Martin 1956:478; Montagu 1960:51; Olivier 1969:152.
Biorbital breadth	ec-ec, EKB	The direct distance from one ectoconchion (ec) to the other.	Howells 1973:178
Interorbital breadth	d-d, DKB	The direct distance between right and left dacryon (d).	Martin 1956:477.
Frontal chord	n-b, FRC	The direct distance from nasion (n) to bregma (b) taken in the midsagittal plane.	Howells 1973:181; Martin 1956:465.
Parietal chord	b-l, PAC	The direct distance from bregma (b) to lambda (l) taken in the midsagittal plane.	Howells 1973:182; Martin 1956:466.
Occipital chord	l-o, OCC	The direct distance from lambda (l) to opisthion (o) taken in the midsagittal plane.	Howells 1973:182; Martin 1956:466.

Statistical Procedures

Calculations are performed using Microsoft Excel 2004 for Macintosh, Version 11.3.3 and SAS 8.3 running on Unix at grove.ufl.edu. A *t*-test is a statistical hypothesis test that follows a Student's *t*-distribution if the null hypothesis is true and the variable is normally distributed. The *t*-test is used to test the null hypothesis that the mean of a variable is the same for males and females against the alternative that the means are different. The value of the *t*-statistic is the difference between the means of the two groups divided by the standard error of the difference. The result is used to identify which variables are likely to be useful in discriminating between male and female crania. The *t*-statistic is calculated using the formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{X}_1 - \bar{X}_2}}$$

where $\bar{X}_1 - \bar{X}_2$ is the difference between the sample means, and $s_{\bar{X}_1 - \bar{X}_2}$ is the standard error of the differences between the two means. For groups of unequal size, $s_{\bar{X}_1 - \bar{X}_2}$ is computed by the formula:

$$s_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{(N_1 - 1)s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2} \left(\frac{1}{N_1} + \frac{1}{N_2} \right)}$$

where s^2 (variance) is calculated by the formula:

$$s^2 = \frac{\sum (x - \bar{x})^2}{(n - 1)}$$

and s^2 is calculated using the VAR function in Excel. The *t*-statistic is then compared to a Student's *t*-distribution with $n-2$ degrees of freedom. This is accomplished using the 'TDIST' function in Excel.

Multiple Analysis of Variance, or MANOVA, is the multivariate equivalent of a *t*-test. It is used to test the null hypothesis that more than two groups do not differ for multiple variables. In

the present case, it is used to test the hypothesis that all of the individuals from the different sites in this research can be considered to be a single group for the purposes of this study. The MANOVA is preformed using SAS PROC GLM.

```
PROC GLM Data=thesisdata ORDER=freq;  
  CLASS site;  
  MODEL GOL XCB ZYB BBH BNL BPL AUB WFB UFBR EKB FRC PAC MDHA= site;  
  MANOVA H=site / PRINTE;
```

The next task is to calculate the results of the Giles and Elliot (1962) function 3 for sex discrimination on the study sample in order to evaluate its accuracy. Sex is first determined using the sectioning point given by Giles and Elliot. The sectioning point is then recalculated using the method described by Giles and Elliot. The average of the function is calculated using the average value of each function for each sex separately,

$$\bar{f}(\bar{f}_m, \bar{f}_f)$$

and the sectioning point is placed midway between the two results. The function is calculated again, replacing missing values with the average of the male and female means for that variable. Accuracy is then evaluated again using the original sectioning point, and the recalculated sectioning point described above.

Once the accuracy of the Giles and Elliot formula is determined, new discriminant functions are calculated based on the data collected. The first function calculated uses the same variables Giles and Elliot used. The second function calculated uses the variables selected using *t*-tests and that showed good preservation as indicated by the proportion of crania from which the measurement could be observed.

Exact binomial probabilities are used to compare the accuracy of new results to Giles and Elliot's (1963) reported accuracy of 86.4%. Exact probabilities are calculated using the SAS

PROC FREQ procedure with the EXACT BINOMIAL option. The null hypothesis is that the accuracy of the formulas is equal against the alternative that the new accuracy is higher.

Fisher's exact test is used to compare the accuracy between sets of new results. Fisher's exact test is a non-parametric statistical hypothesis test used for categorical data where samples are too small for the Chi-squared test. Fisher's exact test is calculated using the PROC FREQ procedure with the CHISQ option. The null hypothesis is that the accuracies are equal, which is tested against the alternative that the accuracies are different.

CHAPTER 7 RESULTS

General Results

This section presents the results of the analysis described in Methods and Materials. Discriminant function scores are calculated for each individual using the Giles and Elliot (1963) formula for sex determination. Each individual is classified as male or female using the sectioning point published by Giles and Elliot. Each individual is classified again using a recalculated sectioning point based on sample data following a method recommended by Giles and Elliot (1963). Using the published Giles and Elliot (1963) sectioning point, the formula correctly classifies 13 of 13 males, and 2 of 4 females. The overall accuracy is 88.24%, but the error is unequally distributed. Using the recalculated sectioning point, the formula correctly classifies 12 of 13 males, and 3 of 4 females. The overall accuracy is still 88.24%, but the error is evenly distributed. This error rate is not significantly different than that reported by Giles and Elliot, but the sample size is unacceptably small due to missing variables.

In order to increase the sample size, missing variables are replaced with the average of the male and female means for each variable. This allows the calculation of the discriminant function to be completed without allowing missing variables to influence sex classification. Discriminant function scores are calculated for each individual using the Giles and Elliot (1963) formula for sex determination. Each individual is classified as male or female using the sectioning point published by Giles and Elliot (1963). Each individual is classified again using a recalculated sectioning point based on sample data following a method recommended by Giles and Elliot. Using the Giles and Elliot sectioning point, the formula correctly classifies 31 of 32 males, and 2 of 13 females. The overall accuracy is 73.33%, but the error is unequally

distributed. Using the recalculated sectioning point, the formula correctly classifies 27 of 32 males, and 11 of 13 females. The overall accuracy is 84.44%, and the error is evenly distributed.

Variables for further analysis are selected using *t*-tests and variable preservation rates. *T*-tests are performed to identify variables that are likely to be useful in discriminating between males and females. Ten variables are significant, including: GOL, BBH, BNL, BPL, AUB, WFB, UFBR, EKB, PAC, and MDH. Five of these variables are excluded from further analysis because their low preservation would have decreased the number of usable individuals to unacceptable levels. The excluded significant variables are: BBH, BNL, BPL, UFBR, and EKB. The variables retained for further analysis are GOL, AUB, WFB, PAC, and MDHA.

A MANOVA is performed using the retained variables to test the null hypothesis that there is no difference between groups. There is not enough evidence to reject the null hypothesis that there is no difference between groups. Therefore, it is concluded that all individuals could be treated as a single group.

Two new discriminant functions are created. The first is created from the sample data using the same variables used by Giles and Elliot (1963). The second is created using the variables identified in the variable selection step. The first step is to create a new formula using the same variables as Giles and Elliot (1963). This is done using PROC DISCRIM in SAS and variables GOL XCB BBH ZYB BPL UFHT MAB MDHA. Again, discriminant function scores could only be calculated for 17 individuals (13 Male and 4 female) due to missing variables. The new function correctly classifies 13 of 13 males and 4 of 4 females, for a combined accuracy of 100%. This is not significantly different from the accuracy of the Giles and Elliot function.

Next, a new function is calculated using the variables identified during variable selection. This is done using PROC DISCRIM in SAS and variables GOL, XCB, AUB, WFB, FRC, PAC,

and MDHA. Discriminant function scores are calculated for 38 individuals, 26 males and 12 females. The new function correctly classifies 11 of 12 females and 24 of 26 males for a combined accuracy of 91.99%. The discriminant function is then applied to the full sample, substituting missing values with the average of the male and female means from the test sample. This function assigned sex correctly to 12 of 13 females and 27 of 32 males, for a total accuracy of 86.67%. This is not significantly different than the accuracy of the Giles and Elliot function.

Specific Results

Giles and Elliot Discriminant Function

Discriminant function scores are calculated for each individual using Giles and Elliot's (1963) discriminant function 3 based on a combined sample of black and white individuals (see Table 2-1, function 3). The purpose of this task is to establish the accuracy of the Giles and Elliot function on Florida and Georgia Native Americans for comparison to new discriminant functions. Thirteen males and four females are complete enough to record all eight measurements needed to use the Giles and Elliot function. Using the sectioning point reported by Giles and Elliot (1963), the formula classifies individuals with discriminant function scores above 6237.95 as male, and individuals below that score as female. The formula correctly classifies all 13 males, but only classifies 2 of 4 females correctly. While the overall accuracy of 88.24% compares well with the Giles and Elliot result of 86%, the error is not equally distributed between males and females. All males are correctly classified while half of the females are misclassified. This violates the requirement of DFA that error be spread equally among groups (Kendal 1957). This type of error is known to occur when a discriminant function is applied to a group that is not included in the development of the formula.

Giles and Elliot report this type of error where they attempt to use their formula on different groups. To avoid this problem, Giles and Elliot recommend recalculating the sectioning

point based on the sample data. Their method is to create a centroid discriminant function score for each sex by using the mean value of each variable to calculate discriminant function scores.

The average of the male and female centroids is used as the sectioning point.

"We can determine the mean value of the discriminant function scores for males by taking the mean male value for each measurement and entering them into the discriminant function. If this is likewise done for the females, the arithmetic mean of the two scores provides a sectioning point to use when we have no a priori reason to believe that a specimen is more likely to be male than female (Kendall 1957). Following this procedure, we will say that any specimen falling on the side of this line toward the male mean will be called male, and any specimen falling on the other side will be called female. So doing should minimize the probability of misclassification (Giles and Elliot 1963).

Table 7-1 Accuracy of the Giles and Elliot function 3 for sex determination on the study sample of Florida and Georgia Native Americans.

	Sectioning Point	Sex	Number Correct	Total (n)	Accuracy
Individuals with missing variables omitted	Giles and Elliot Sectioning Point (6237.95)	overall	15	17	88.24%
		male	13	13	100.00%
		female	2	4	50.00%
	Recalculated Sectioning Point (6513.392571)	overall	15	17	88.24%
		male	12	13	92.31%
		female	3	4	75.00%
Missing variables replaced with average of the male and female means	Giles and Elliot Sectioning Point (6237.95)	overall	33	45	75.56%
		male	32	32	100%
		female	2	13	15.38%
	Recalculated Sectioning Point (6513.392571)	overall	38	45	84.44%
		male	27	32	84.375%
		female	11	13	84.615%

The male centroid is 6731.518743, the female centroid is 6295.266398, and the recalculated sectioning point is 6513.392571. Using the recalculated sectioning point, the overall accuracy remains the same, but errors are evenly distributed. The function correctly sexed 12 of 13 males and 3 out of 4 females. The accuracy of the formula using the recalculated sectioning point is not significantly different from the result reported by Giles and Elliot for males ($p=0.9109$), females ($p=0.8855$) or males and females combined ($p=1.0000$).

In order to increase sample size, missing variables are replaced with the average of the male mean and the female mean for each variable. This allows the discriminant function to be calculated without the missing observation influencing the final classification.

With the missing variables replaced and using the Giles and Elliot sectioning point, 31 out of 32 males ($p=0.1123$) are correctly classified, but only 2 out of 13 females ($p<.0001$) are correctly classified. Both of these results are significantly different from both Giles and Elliot's result and from each other ($p<0.0001$). With the sectioning point recalculated, 28 out of 32 males are correctly classified, and 10 out of 13 females are correctly classified. The results using the repositioned sectioning point are not significantly different from the Giles and Elliot result for males ($p=1.0000$), females ($p=0.5112$), or male and females combined ($p=0.8283$).

Variable Selection

The goal of variable selection is to select for further analysis those variables that are likely to aid in the discrimination of males and females, and that are likely to be preserved for measurement. Variables are selected for further analysis using *t*-tests and variable preservation rates. *T*-tests are performed for all cranial variables for a difference in mean between males and females (Table 7-2). This is done in order to identify variables likely to be useful in discriminant function analysis. The *t*-test tests the null hypothesis that there is no difference between the male and female means of a variable against the alternative that there is a difference. A variable whose mean is not significantly different between males and females is unlikely to contribute to sex discrimination. A variable that is poorly preserved in the present sample would reduce the sample size to unacceptable levels, and is likely to limit the applicability of this research in other cases.

Table 7-2. *T*-scores and p-values for a difference in mean values of each cranial variable between males and females. Significant values are in italics. Variables with acceptable preservation that are used in further analysis are in bold face.

Cranial Measurement	Male Count	Female Count	Total Count	<i>T</i> -statistic	P-value
GOL	30	12	42	-3.25	<i>0.0024</i>
XCB	29	12	41	-2.25	0.0310
ZYB	15	4	19	-2.84	0.0113
BBH	27	11	38	-3.12	<i>0.0036</i>
BNL	27	10	37	-3.28	<i>0.0023</i>
BPL	26	9	35	-2.96	<i>0.0057</i>
MAB	25	8	33	-0.15	0.8835
MAL	24	10	34	-1.34	0.1889
AUB	30	13	43	-3.63	<i>0.0008</i>
UFHT	28	10	38	-0.79	0.4356
WFB	31	12	43	-3.16	<i>0.0030</i>
UFBR	29	11	40	-2.73	<i>0.0096</i>
NLH	28	10	38	-1.13	0.2679
NLB	27	10	37	-0.53	0.6000
OBB	26	10	36	-1.44	0.1577
OBH	27	10	37	-0.25	0.8047
EKB	25	10	35	-2.73	<i>0.0100</i>
DKB	25	10	35	-2.36	0.0242
FRC	32	12	44	-1.40	0.1696
PAC	32	13	45	-3.63	<i>0.0008</i>
OCC	30	11	41	-.11	0.9135
FOL	27	10	37	-1.53	0.1360
FOB	25	11	36	-1.82	0.0770
MDHR	28	13	41	-4.01	<i>0.0003</i>
MDHL	27	9	36	-2.70	0.0106
MDHA	31	13	44	-3.92	<i>0.0003</i>

Thirteen of the 26 measurements are significant at the alpha=0.01 significance level, including left, right and average mastoid length (Table 7-2). The significant variables are: Glabella-occipital length (GOL); Basion-Bregma height (BBH); Basion-nasion (BNL); Basion-prosthion (BPL); Left, right and average Mastoid height (MDHL, MDHR, MDHA); Parietal chord (PAC); Biauricular breadth (AUB); Minimum frontal breadth (WFB); Upper facial breadth (UFBR); and Biorbital breadth (EKB). Giles and Elliot's function 3 includes the significant

variables GOL, BBH, BPL, and MDH. Variables included in the Giles and Elliot formula which are not significant are: XCB, ZYB, and MAB.

A variable is considered to be poorly preserved if it is not observable in at least 90% of cases for each sex. For this sample, the variable has to be observable in at least twelve females and at least 29 males. Five of the significant variables, BBH, BNL, BPL, MDHR, and MDHL, are excluded because of poor preservation. Five variables, GOL, AUB, WFB, PAC, and MDHA, meet the criteria for significance and preservation. These five variables are used in discriminant function analysis for the determination of sex in Florida and Southern Georgia Native Americans.

Test for Site Effect on Selected Variables

The purpose of testing for site effect is to determine if individuals from different sites in Florida and Georgia can be treated as a single population. If there is no significant site effect, then a single discriminant function for sex determination can be used for all sites.

Table 7-3 F values and P values for the hypothesis of no site effect for each variable using type IV sums of squares and cross products.

Variable	DF	F	P
GOL	8	1.35	0.2581
AUB	8	3.11	0.0116
WFB	8	1.60	0.1688
PAC	8	1.31	0.2756
MDHA	8	0.61	0.7620

An ANOVA is first performed on individual variables to test for the effects of site (Table 7-3). There is no significant site effect for any of the variables at the 0.01 alpha-level. There is a significant site effect for AUB at the 0.05 alpha-level. This difference is driven by a difference between the Casey Key site and the Golf Course site, each of which is represented by one individual. For this variable, the individual from Golf Course is a larger-than-average male, and

the Casey Key individual is an unusually small female. There is not enough evidence to justify rejecting the null hypothesis, eliminating the variable AUB, or eliminating either site.

The MANOVA test is the multivariate equivalent to an ANOVA. It is used in cases where there are multiple metric dependent variables, and one or more categorical independent variables. It is used to test the null hypothesis that there is no overall difference between sites for the array of variables included in this study. The sex of the individual is also used as an independent variable so that all individuals can be included, and site difference is controlled for sex differences.

Table 7-4 MANOVA test criteria and F approximations for the hypothesis of no overall site effect, using type IV sums of squares and cross products.

Statistic	Value	F Value	DF	Pr > F
Wilks' Lambda	.1636	1.44	40	0.0709
Pillai's Trace	1.387	1.39	40	0.0817
Hotelling Lawley Trace	2.483	1.48	40	0.0830

In the MANOVA test, all variables are considered as a single array to test the null hypothesis that site has an effect on the array of cranial measurements against the alternative that there is a site effect. SAS provides three approximations of the F for a MANOVA, Wilk's Lambda, Pillai's Trace and the Hotelling- Lawley Trace. None of the statistics are significant at the 0.05 alpha-level, so there is not enough evidence to reject the null hypothesis (Table 7-4). This indicates that it is reasonable to treat all sites as a single group for this analysis.

Discriminant Function Analysis

The goal of the discriminant function analysis is to produce a linear formula that can be used with cranial data to accurately assign sex to Native American skeletal remains recovered from Florida archaeological sites. To use the function, each variable is multiplied by the corresponding coefficient and the results and constant are summed. If the result is greater than

the sectioning-point, the individual is categorized as male. If it is less than the sectioning point, the individual is categorized as female.

This analysis presents two discriminant functions. Function 1 uses the same eight variables used by Giles and Elliot in their discriminant function analysis, but the function is calculated using a sample of thirteen male and four female Native Americans from Florida and Southern Georgia (Table 7-5). Function 2 uses the five variables selected based on *t*-tests and preservation rates as described above, and it is calculated from 27 males and 12 females. The coefficients, constants, and sectioning points for this analysis are presented in table 7-5.

Table 7-5 Coefficients, group means, and sectioning points for Function 1 and Function 2.

Cranial variable	Function 1 coefficients	Function 2 coefficients
AUB		0.0696568389
WFB		0.0138332675
PAC		0.1046833664
GOL	-.0717749505	-0.0325698854
MDHA	0.1075559971	0.2188344979
XCB	0.1456008386	
BBH	-0.0620766571	
ZYB	0.2196351470	
BPL	0.4499153016	
UFHT	-0.2704566313	
MAB	-0.1675593848	
Constant	-49.19563	-21.50963
Male Mean	1.007282992	0.744143627
Female Mean	-3.273669725	-1.674323160
Sectioning Point	-1.133193367	-0.470560251
Constant=0 Sectioning Point	48.062436633	21.039069749

Function 1 Accuracy

Only 17 individuals included all of the measurements required for Function 1. Because of the small sample size, the function is tested on the same individuals used to develop the function. When applied to the sample of thirteen males and four females from which it is developed,

Function 1 correctly assigned sex to all seventeen individuals (Table 7-6). This result is not significantly better than the reported Giles and Elliot result ($p = 0.0509$). It is also not significantly different than the Giles and Elliot formula applied to the current sample when observations with missing variables are omitted ($p = 0.4848$). The accuracy of this function is inflated in this test due to the small sample size. A better indication of the accuracy of the function is given by cross validation.

Table 7-6. Accuracy of Function 1, which uses the variables originally used by Giles and Elliot (1963).

	Sex	Number correct	Count (n)	Percent
Cross validation	Overall	14	17	82.35%
	Male	11	13	84.62%
	Female	3	4	75.00%
Individuals with missing variables omitted	Overall	17	17	100%
	Male	13	13	100%
	Female	4	4	100%
Missing variables replaced by the average of the male and female means	Overall	35	45	77.78%
	Male	24	32	75%
	Female	11	13	84.62%

Cross validation classifies each observation based on all of the other observations. A discriminant function is calculated for the dataset minus one observation, and the omitted observation is classified using the resulting function. This procedure provides a more realistic estimate of the accuracy of the discriminant function. Using cross validation, a discriminant function analysis using the Giles and Elliot variables correctly classified eleven of thirteen males and three of four females, for a combined accuracy of 82.35%. This is not significantly better than the Giles and Elliot result ($p = 0.4130$). It is also not significantly different than the Giles and Elliot formula applied to the current sample when observations with missing variables are omitted ($p = 1.00$).

In order to apply Function 1 to all observations, missing variables are replaced with the average of the male and female means for each variable. With missing variables replaced, Function 1 correctly classifies 24 of 32 males and 11 of 13 females, for an overall accuracy of 77.78% (Table 7-6). This is not significantly different from the Giles and Elliot function using the recalculated sectioning point and missing variables replaced with the average of the male and female means ($p= 0.5912$).

Function 2 Accuracy

Function 2 is based on measurements from 39 individuals, including 27 males and 12 females. When applied to the sample from which it is developed, Function 2 correctly assigns sex to 26 of 27 males and 10 of 12 females, for an overall accuracy of 92.31% (Table 7-7). This is not significantly different from Giles and Elliot’s reported accuracy of 86.4% ($p= 0.4087$). Using cross validation, the formula correctly classifies 10 of 12 females and 23 of 27 males for an overall accuracy of 84.62%. This is not significantly different from the accuracy of the Giles and Elliot function ($p= 0.8819$).

Table 7-7. Accuracy of Function 2, which uses variables selected using *t*-tests and preservation rates.

	Sex	Number correct	Count (n)	Accuracy
Cross validation	Overall	33	39	84.26%
	Male	23	27	85.19%
	Female	10	12	83.33%
Individuals with missing variables omitted	Overall	36	39	92.31%
	Male	26	27	96.30%
	Female	10	12	83.33%
Missing variables replaced by the average of the male and female means	Overall	39	45	86.87%
	Male	28	32	87.50%
	Female	11	13	84.62%

To apply Function 2 to all individuals in the sample, missing variables are replaced by the average of the male and female means for each variable. With the missing variables replaced,

Function 2 correctly classified 28 of 32 males and 11 of 13 females for an overall accuracy of 86.87%. The accuracy of Function 2 is not significantly different than the Giles and Elliot (1963) formula applied to the current sample using the recalculated sectioning point and missing variables replaced with the average of the male and female means ($p= 1.00$).

CHAPTER 8 CONCLUSIONS AND DISCUSSION

Conclusions

The most significant finding of this research is that the function derived by Giles and Elliot does not accurately sex skeletons from Florida and Georgia unless the sectioning point is adjusted. Using the sectioning point published by Giles and Elliot (1963), the function classifies only 15.38% of females correctly. When the sectioning point is adjusted using male and female averages for each variable, the function classifies about 84% of males and females correctly. For Florida and Georgia Native Americans, the sectioning point should be changed to 6513.4 when using Giles and Elliot's (1963) function 3.

The overall goal of this research is to determine if the accuracy of discriminant function analysis for sex determination could be improved by using local or regional populations, and by better variable selection. Previous research has tested the Giles and Elliot (1963) discriminant functions on Finnish crania and developed functions for that population (Kajanoja 1966). Other research has developed discriminant functions for fragmentary archaeological post-cranial remains from other areas (Bass 1995; Black 1978; Krogman and Iscan 1986). None of the previous studies focuses on comparing the established Giles and Elliot methods to new formula developed from fragmentary crania from Southeastern archaeological sites, thus making this research novel. This research is also novel in treating all prehistoric Native Americans in Florida and Georgia as a single population, regardless of time period. This study addresses the following hypotheses related to sex determination by discriminant function analysis (DFA):

- For archaeological populations, higher accuracy in sex determination by DFA can be achieved drawing a sample from the archaeological population than by using a dissecting room sample.
- Sex determination by DFA can be accomplished with a smaller number of more robust measurements without reducing accuracy.

- For the purpose of sex determination by DFA, Florida and Georgia Native Americans can be viewed as a single population, regardless of time period.

There is evidence that better discriminant functions can be developed using local populations, but the results are not statistically significant possibly because of the small sample size. Sample size is small because of the requirement that individuals include both a relatively intact cranium and pubic bone. Both of these skeletal elements are relatively delicate and are seldom preserved intact. Individuals who have both elements intact are rare.

There is evidence that sex determination by DFA can be accomplished with a smaller number of more robust variables than those used by Giles and Elliot without reducing accuracy. Five variables are identified that are preserved in at least 90% of males and females selected for this study. It is possible to apply the discriminant function using these variables to 86.66% of the sample, compared to just 37.77% for the Giles and Elliot variables. The new function also has higher accuracy than the function developed using the Giles and Elliot variables, although the difference is not significant.

Implicit in this research is the assumption that all of the sites used in this study can be considered a single population. The results of the Multiple Analysis of Variance (MANOVA) suggest that there is no significant difference between individuals from the different sites used in this study. It is, therefore, reasonable to treat all of the individuals from these sites as belonging to a single population.

Summary of Statistical Results

The results presented in the previous chapter can be summarized as follows. When applied to Florida and Georgia Native Americans:

- The Giles and Elliot function 3 and original sectioning point classifies males correctly, but misclassifies females at a significantly higher rate than other methods.

- The accuracy of the Giles and Elliot function 3 with the sectioning point recalculated is not significantly different from the Giles and Elliot function applied to black and white individuals.
- The Giles and Elliot function includes some variables that do not contribute to sex discrimination, and others that preserve poorly.
- The accuracy of a new discriminant function developed using the Giles and Elliot variables (GOL, XCB, BBH, ZYB, BPL, UFHT, MAB, and MDHA) is no more accurate than the original Giles and Elliot function.
- Variables which do contribute to sex discrimination and preserve well include: GOL, AUB, WFB, PAC, and MDHA.
- GOL, AUB, WFB, PAC, and MDHA are not significantly different across the samples sites in Florida and Georgia individually, or taken together.
- The accuracy of a new discriminant function developed using GOL, AUB, WFB, PAC, and MDHA is more accurate than the Giles and Elliot function, but the difference is not significant.

Specific Statistical Results

Other researchers have found that the Giles and Elliot formula cannot be applied to other populations without modification (Giles and Elliot 1963, Kajanoja 1966). While Giles and Elliot suggested several methods for recalculating a sectioning point, Henke (1977) and Calcagno (1981) have determined that those methods are not practical.

Using the Giles and Elliot function with the original sectioning point did not produce acceptable results. The function is able to classify 13 of 13 males correctly, but misclassified 2 of 4 females. When missing values are replaced with neutral values, the Giles and Elliot function classifies all 32 males correctly, but misclassifies 11 of 13 females. The Giles and Elliot function is not a reliable indicator of sex for Florida and Georgia Native Americans using the original sectioning point. The Giles and Elliot function does produce acceptable results when the sectioning point is recalculated.

In terms of accuracy, Function 1 correctly categorizes all individuals in the initial sample, but did not do as well overall in cross validation or when missing values are substituted with neutral values. The accuracy of Function 1 is not significantly different from the Giles and Elliot function. Since it is based on the same variables, Function 1 suffers from the same issues of applicability as the Giles and Elliot function. Function 1 could only be applied to 2 of 13 females, and 15 of 32 males.

Function 2 is more accurate across the board than the Giles and Elliot function, but the difference is not statistically significant. Accuracies are almost identical in cross validation and when missing values are substituted with neutral values. Function 2 offers better applicability than the Giles and Elliot function. Where the Giles and Elliot function could be applied to 2 of 13 females and 15 of 32 males, Function 2 could be applied to 12 of 13 females and 27 of 32 males.

Discussion

The goal of the research is to determine if new discriminant functions for sex determination could be developed for Florida and Georgia Native American populations that are better than the functions presented by Giles and Elliot (1963). While neither Function 1, which uses the Giles and Elliot variables, nor Function 2, which uses more robust variables, did significantly better than the Giles and Elliot function, Function 2 could be used on more than twice as many individuals without having to substitute missing variables.

While neither of the two new functions are significantly better than the Giles and Elliot function with a recalculated sectioning point, there is reason to believe that creating new functions might be beneficial. The first has to do with the problems involved with calculating the new sectioning point. The second problem has to do with sample size and the power of the statistics used here.

Several authors point out the problem of using discriminant functions developed for one population on another and conclude the problem of recalculating the sectioning point has no practical solution (Henke 1977, Calcagno 1981). Using the midpoint of the male and female mean score for a function produces a workable sectioning point, but requires a sufficient number of male and female individuals whose sex has already been identified. This is a problem akin to opening a crate with the enclosed crowbar. If there are enough individuals whose sex has been identified it is almost as easy to create a new discriminant function as it is to recalculate the sectioning point. The Giles and Elliot function can be made to work across populations by recalculating the sectioning point, but does not take full advantage of the power of DFA to separate groups. Regional differences in shape are going to add within-group variance, which is going to work to reduce the effectiveness of the function. A function developed on a group includes regional differences as part of the calculation. A discriminant function created from the population under study should have a higher ratio of between-group to within-group variation and be more accurate if the sample size is sufficiently large. If the sample size is too small, the function may be skewed by idiosyncratic variation within the sample.

Another problem with small sample sizes is a lack of statistical power. Statistical power is the ability of a hypothesis test to detect a difference. The larger the sample size, the higher the statistical power, and the smaller the difference a hypothesis test can detect. In the present study, Function 1 is more accurate than the Giles and Elliot function, but there is not enough statistical power for the difference to be significant because of the small sample size.

If one considers individuals who could not be sexed due to missing variables as incorrect, then Function 1 does significantly better than the Giles and Elliot function ($p < 0.0001$). Function

1 is able to correctly classify 36 of 45 individuals (80%), while the Giles and Elliot function correctly classified 15 of 45 individuals (33.33%).

This research draws on sites and individuals ranging from the Archaic to the Spanish mission periods, and should be applicable to any remains from that time range found in Florida. This research does not use any Paleoindian remains because they are so rare. Therefore, the functions developed here are not recommended for use in determining the sex of Paleoindians.

One might argue that all Native Americans from the Archaic to the Spanish Mission period from Florida and Georgia is too diverse a group to be considered a single population. The MANOVA test results show that there is no significant between-site difference for these groups. The Giles and Elliot function uses blacks and whites from dissecting room collections, and that function works well for both of those groups. It is hard to argue that blacks and whites are a single population, but that Native Americans from a limited geographic area are not, even if the Native Americans are from a broad time span. The Giles and Elliot discriminant function works well for both blacks and whites, and there is no reason to believe that the functions developed in this research would not work as well for any Native Americans recovered from Florida or Georgia.

Future Research

Because of the small sample size used in this research and the lack of significant improvement over the established Giles and Elliot function, using Function 1 is not recommended without further testing. It should be possible to generate larger samples using Function 1 because the variables it uses are more robust than the ones used by Giles and Elliot. Because of Function 1's potential for application to a larger number of less well-preserved crania and potentially greater accuracy, it should be tested on a larger sample. Future tests should include as many sites from Florida and Georgia as possible.

This study demonstrates that when using discriminant function analysis missing variables can be replaced with the average of the male and female means with good results, although the limits of this method are not explored. One potential line of future research is to determine how robust discriminant functions are to this method of replacing missing variables.

One of the purported advantages of discriminant function analysis is that the functions can be used by individuals with relatively little training. This assumption needs to be tested. A study where students with little or no osteology training are asked to measure crania and use discriminant functions to determine sex should be performed. Their results could be compared to a group of students given an identical amount of training in visual methods.

APPENDIX A
CRANIAL MEASUREMENT DEFINITIONS

Giles and Elliot Measurements

The following are the ten measurements used by Giles and Elliot in their 1963 study. The name of the measurement is followed by the measurement's abbreviation, Giles and Elliot's description of the measurement, the name of the equivalent Howells/FORDISC measurement, and the method used to record the measurement. Detailed descriptions of cranial points and landmarks can be found in Bass (1995), White (1991), and others.

Glabello-occipital length (g-op, GOL): Maximum length of the skull, from the most anterior point of the frontal in the midline to the most distant point on the occiput in the midline. This measurement is equivalent to Maximum Cranial Length; the distance of Glabella (g) from Opisthocranium (op) in the mid sagittal plane measured in a straight line using spreading calipers. The skull is placed on its side for this measurement. The endpoint of the left branch of the caliper is placed on Glabella and held with fingers while the endpoint of the right branch of the caliper is applied similarly to the posterior portion of the skull in the mid sagittal plane until the maximum length is obtained (Bass 1971:62; Howells 1973:170; Martin 1956:453; Olivier 1969:128).

Maximum width (eu-eu, XCB): The greatest breadth of the cranium perpendicular to the median sagittal plane, avoiding the supra-mastoid crest. This measurement is equivalent to Maximum Cranial Breadth; the maximum width of the skull perpendicular to the mid-sagittal plane wherever it is located with the exception of the inferior temporal line and the immediate area (i.e. the posterior roots of the zygomatic arches) measured with spreading calipers. The Maximum Cranial Breadth is measured with the skull resting either on its base or on the occiput. The two measuring points lie in the same horizontal and frontal planes. The arms of the caliper are placed at the same level while maintaining the hinge joint of the caliper in the mid sagittal

plane. The ends of the caliper are held in each hand and applied to the lateral portions of the skull, making circular motions until the maximum breadth is obtained. Areas below the squamosal suture are included, where the maximum is sometimes found (Bass 1971:62; Howells 1973:172; Hrdlička 1952:140; Martin 1956:455; Montagu 1960:44).

Basion-bregma height (ba-b, BBH): Cranial height measured from basion to bregma. This measurement is equivalent to Basion Bregma Height; the direct distance from the lowest point on the anterior margin of the foramen magnum, basion (ba), to bregma (b) is measured with the spreading caliper. The skull is placed on its side and the endpoint of one of the arms of the caliper is placed at the most inferior point of the margin of the foramen magnum in the mid sagittal plane and supported with fingers. Then the endpoint of the second arm of the caliper is applied to bregma (Bass 1971:62; Howells 1966:6; Martin 1956:459; Olivier 1969:129).

Maximum diameter bi-zygomatic (zy-zy, ZYB): Maximum width between the lateral surfaces of the zygomatic arches measured perpendicular to the median sagittal plane. This measurement is equivalent to Bizygomatic Breadth; The direct distance between each zygon (zy), located at the most lateral points of the zygomatic arches measured with a sliding caliper. The skull is placed on its base, and the blunt points of the caliper are applied to the zygomatic arches and the maximum breadth is recorded (Bass 1971:67; Martin 1956:476).

Basion-nasion(ba-n, BNL): Distance from basion to nasion. Equivalent to Cranial Base Length: The direct distance from nasion (n) to basion (ba) measured using the spreading caliper. The skull is placed with the cranial vault down on a cork or sandbag skull-ring. The endpoint of the one arm of caliper is applied to nasion (n) while the other is applied to the anterior border of the foramen magnum in the mid sagittal plane. This measurement is not taken where anomalous

growths occurred on the anterior border of the foramen magnum (Howells 1966:6; Martin 1956:455).

Basion-prosthion (ba pr, BPL): Distance from basion to the most anterior point on the maxilla in the median sagittal plane. Equivalent to Basion Prosthion Length; The direct distance from basion (ba) to prosthion (pr) measured using a spreading caliper, or sliding caliper where the foramen magnum obstructs the use of spreading calipers or in crania in which the central incisors have been lost. The fixed point of the sliding caliper or one tip of the spreading caliper is applied to the most anterior point on the alveolar process in the mid sagittal plane. The movable point of the sliding caliper or the other tip of the spreading caliper is then brought to the margin of the anterior border of the foramen magnum in the mid sagittal plane (Martin 1956:474).

Nasion breadth (al-al, NLB): Maximum breadth of the nasal aperture perpendicular to nasal height. Equivalent to Nasal Breadth; the maximum breadth of the nasal aperture measured with a sliding caliper. The points of the instrument are placed on the sharp lateral margins of the nasal aperture at its most lateral curvature. The measurement is taken perpendicular to the mid sagittal plane and recorded to the nearest millimeter (Bass 1971:68; Howells 1973:176; Martin 1956:479; Montagu 1960:50; Olivier 1969:153).

Palate-external breadth (ecm-ecm, MAB): The maximum breadth of the palate taken on the outside of the alveolar borders. Equivalent to Maxillo-Alveolar Breadth and External Palate Breadth; the maximum breadth across the alveolar borders of the maxilla measured at its widest point between each ectomolare (ecm). The maximum breadth is usually found at the level of the second molars. Using a spreading caliper, both arms of the caliper are applied to the alveolar borders above the tooth row from an anterior position. The points of measurement (ecm) are usually not found on the alveolar processes, but are located on the bony segment above the

second maxillary molars. (Bass 1971:70; Howells 1973:176; Martin 1956:480; Montagu 1960:51).

Opisthion-forehead length: The maximum distance from opisthion (the midpoint on the posterior border of the foramen magnum) to the forehead in the midline. This measurement is not used in this study because it is not used in the Giles and Elliot formulas, nor has it survived in the current literature.

Mastoid length (MDH): The length of the mastoid measured perpendicular to the plane determined by the lower borders of the orbits and the upper borders of the auditory meatuses (Frankfort horizontal plane). Equivalent to Mastoid Length; The projection of the mastoid process below, and perpendicular to, the Frankfort horizontal plane in the vertical plane. Both right and left sides are measured using a sliding caliper. The skull is rested on its right side, and the calibrated bar of the caliper is applied just behind the mastoid process, with the fixed flat arm tangent to the upper border of the auditory meatus and pointing (by visual sighting) to the lower border of the orbit. The calibrated bar is perpendicular to the eye ear plane of the skull (i.e., approximately level in the position given). The measuring arm is adjusted until it is level with the tip of the mastoid process, using the base of the skull generally, and the opposite mastoid process to control the plane of sighting. (Howells 1966:6, 1973:176; Keen 1950).

Other Measurements

The remaining measurements are not included in the Giles and Elliot (1962) study, but are used in more recent research, including Bass (1971, 1995), Howells (1973), Buikstra and Ubelaker (1994), and FORDISC 2.0 materials (Ousley and Jantz 1996). The descriptions and techniques primarily follow Ousley and Jantz (1996).

Biorbital Breadth (ec-ec, EKB): The direct distance from one ectoconchion (ec) to the other. This measurement is taken using the sliding caliper (Howells 1973:178).

Interorbital Breadth (d-d, DKB): The direct distance between right and left dacryon measured using a sliding caliper (Martin 1956:477).

Maxillo-Alveolar Length, External Palate Length (pr-alv, MAL): The direct distance from prosthion (Hrdlička's prealveolar point) to alveolon (alv) measured using a Spreading or sliding caliper. A sliding caliper is used only in crania in which the central incisor teeth have been lost. The skull is placed with the cranial vault down on a cork or sandbag skull-ring so the base is facing up. A rubber band is applied to the posterior borders of the alveolar arch and the distance measured from the anterior prosthion to the middle of the band in the midsagittal plane (Bass 1971:70; Hrdlička 1952:146 147; Martin 1956:480).

Biauricular Breadth (au-au, ALB): The least exterior breadth across the roots of the zygomatic processes, wherever found, measured using a sliding caliper. With the skull resting on the occiput and with the base toward the observer, the outside of the roots of the zygomatic process are measured at their deepest incurvature, generally slightly anterior to the external auditory meatus, with the sharp points of the caliper. This measurement makes no reference to standard landmarks of the ear region. (Howells 1973:173).

Upper Facial Height (n-pr, UFHT): The direct distance from nasion (n) to prosthion (pr) measured using a sliding caliper. The fixed point of the caliper is placed on nasion and the movable point is applied to the tip of the alveolar border between the upper central incisors. If the alveolar process exhibited slight resorption or erosion at the point of prosthion, the projection of the process is estimated when the alveolar process of the lateral incisors is still intact. This measurement is not taken when resorption or erosion is more pronounced (Howells 1966:6; Hrdlička 1952:143; Martin 1956:476). This differs from Howells' NPH in using the inferior border of the alveolar process rather than the most anterior point.

Foramen Magnum Length (ba-o, FOL): The direct distance of basion (ba) from opisthion (o) measured using a sliding caliper. The tips of the instrument are applied on the opposing edges of the border of the foramen magnum along the sagittal plane (Martin 1956:455).

Minimum Frontal Breadth (ft-ft, WFB): The direct distance between the two frontotemporale measured with a sliding caliper. With the skull placed on its base, the two endpoints of the caliper are placed on the temporal ridges at the two frontotemporale, and the least distance between both temporal lines on the frontal bone is recorded (Bass 1971:67; Hrdlička 1952:142; Martin 1956:457; Olivier 1969:151).

Foramen Magnum Breadth (FOB): The distance between the lateral margins of the Foramen magnum at the point of greatest lateral curvature measured with a sliding caliper (Martin, 1956:459).

Upper Facial Breadth (UFBR, fmt-fmt): The direct distance between each frontomale temporale measured using a sliding caliper. The measurement is taken between the two external points on the frontomalar suture (Martin 1956:475). UFBR differs from Howells' FMB in that the lateral most points on the suture are used rather than the most anterior points.

Nasal Height (n-ns, NLH): The direct distance from nasion (n) to nasospinale (ns) measured using a sliding caliper. The direct distance from nasion to the midpoint of a line connecting the lowest points of the inferior margin of the nasal notches is measured (Bass 1971:68; Howells 1966:6; Martin 1956:479; Olivier 1969:153).

Orbital Breadth (d-ec, OBB): The laterally sloping distance from dacryon (d) to ectoconchion (ec) measured using a sliding caliper. The left orbit is measured for standardization and practical reasons where available. If the left orbit is damaged or otherwise could not be

measured, the right orbit is measured and the side recorded on the measurement sheet (Martin 1956:477 478; Howells 1973:175).

Orbital Height (OBH): The direct distance between the superior and inferior orbital margins measured using a sliding caliper. Orbital height is measured perpendicular to orbital breadth and similarly bisects the orbit. The measuring points are located on the opposing margins of the orbital borders. Any notches or depressions on either superior or inferior borders are avoided and the margin is projected when necessary (Bass 1971:69; Martin 1956:478; Montagu 1960:51; Olivier 1969:152).

Biorbital Breadth (ec-ec, EKB): The direct distance from one ectoconchion (ec) to the other measured using a sliding caliper (Howells 1973:178).

Interorbital Breadth (d-d, DKB): The direct distance between right and left dacryon measured with a sliding caliper (Martin 1956:477).

Frontal Chord (n-b, FRC): The direct distance from nasion (n) to bregma (b) taken in the midsagittal plane using a sliding caliper. The skull is rested on its right side to view the left profile of the frontal region. The tips of the instrument are placed on the bone surface or at the level of this surface and not in a suture or other depression (Howells 1973:181; Martin 1956:465).

Parietal Chord (b-l, PAC): The direct distance from bregma (b) to lambda (l) taken in the midsagittal plane measured with a sliding caliper. The skull is left in the same position used to measure the Frontal Chord (above). The tips of the instrument are placed on the bone surface or at the level of this surface and not in a suture or other depression (Howells 1973:182; Martin 1956:466).

Occipital Chord (l-o, OCC): The direct distance from lambda (l) to opisthion (o) taken in the midsagittal plane measured using a sliding caliper. The skull is left in the same position used to measure the Frontal Chord (above). The tips of the instrument are placed on the bone surface or at the level of this surface and not in a suture or other depression. The point of the movable branch of the caliper is placed against the posterior border of the foramen magnum and held in place with the right thumb (Howells 1973:182; Martin 1956:466).

APPENDIX B
TABLE OF SITES

Site name	Sex overall	Catalog #
Golf Course site (8Br44), Brevard county, Florida. "Melbourne Man"	male	331422
Bay Pines (8Pi64) Pinellas county, Florida. (Gallagher and Warren 1975) 24 burials	male	s0272
Canaveral (8Br85), Brevard county, Florida. The Canaveral site includes the Burns and Fuller mounds. Rouse (1951) places the mounds in the Malabar I, Malabar I', and Malabar II cultures based on ceramic types. Malabar is an Indian River variation of St. Johns (500 B.C.-AD1763).	female	377440
		377475
		377503
	male	377427
		377428
		377441
		377465
		377466
		377467
		377471
		377478
		377481
		377484
		377489
		377502
	377507	
	377513	
	377602	
	377605	
Cannon's Point, St. Simons Island, Glynn County, Georgia. Late Wilmington culture ceramic assemblage, radiocarbon dated to 990±75 (A.D. 960) (Martinez 1975; Milanich 1977)	male	s0418
Casey Key (8So17) Sarasota County, Florida. A Manasota Weeden Island culture mound dating from ca. A.D. 250-750. (Bullen and Bullen 1976).	female	92733
Couper Field/Indian Field, Glynn County, Georgia. St. Simons Island. Late Pre-Columbian/early Spanish colonial/mission period village.	female	s0300
		s0301
		s0302
		s0311
	male	s0299
	s0303	
	s0304	
	s0305	
	s0309	
Garfield Site (9Br57) Bartow County, Georgia. Kellog culture (Early Woodland, ca. 600BC-AD 100) village on Etowah River. 18 Burials. (Milanich 1975; Wood and Bowan 1995:8).	male	s0325
	female	97533

Palmer Site (8So2a) Sarasota County, Florida. Gulf coast. Archaic, Early Woodland, Middle Woodland, and Late Woodland. Final MNI 429. (Bullen and Bullen 1976, Miller 1974, Almy and Luer 1993, Kozuch 1998, Hutchinson 2004:49)	female	97533
Palmer Site (8So2a) Sarasota County, Florida. Gulf coast. Archaic, with Early Woodland and Middle Woodland (Wildey at 04906Lah82) Final MNI 429. (Bullen and Bullen 1976, Miller 1974, Almy and Luer 1993, Kozuch 1998, Hutchinson 2004:49)	female	373499 373552
	male	373493 373530
Taylor Mound, St. Simons Island, Georgia. Historic period (AD1600-1650) ceremonial mound. 11 total burials. Same sociocultural population as Couper Field (Wallace 1975).	Unknown	s0385
	female	s0361 s0368
	male	s0362 s0365 s0367 s0371

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BIOGRAPHICAL SKETCH

Michael McGinnes, who grew up in Gainesville, Florida, earned an Associate of Science degree in photography from the Southeast Center for Photo/Graphic Studies at Daytona Beach Community College, an Associate of Arts degree from Santa Fe Community College, and a bachelor's degree from the University of Florida. He has been employed as a professional archaeologist since 1995 and specializes in mortuary archaeology. He has conducted field projects in Panama, Florida, Georgia, South Carolina, Delaware, Oklahoma, Texas, Alabama, Maryland, Virginia, and the District of Columbia. At the National Museum of Natural History, Smithsonian Institution, he worked as the bibliographic research assistant for the Southeast volume of the *Handbook of North American Indians*, and was an intern for the collections manager of the physical anthropology collections. He is married to Dr. Ruth Trocolli, the archaeologist of the District of Columbia.