PALEODEMOGRAPHY OF HIGHLAND BEACH: REEXAMINING THE DEMOGRAPHIC PARAMETERS OF A NATIVE AMERICAN POPULATION FROM SOUTHEASTERN FLORIDA

by

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Douglas Broadfield, Department of Anthropology, and has been approved by the members of his supervisory committee. It was submitted to the faculty of the Dorothy F. Schmidt College of Arts and Letters and was accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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ABSTRACT

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Those who practice within the field and those who wish to discredit the field have long debated the field of paleodemography. In 1999 and again in 2000, researchers who used paleodemographic analysis assembled in Rostock, Germany to amend the present issues and change the way research is conducted in the future (Hoppa and Vaupel 2002). As a result of these meetings, researchers created the Rostock Manifesto. While many scholars accepted the change in the suite of methodologies carried out under the new guidance, little has been said on the effectiveness of the manifesto. In this thesis, I argue that the Rostock Manifesto, at the very least, is effective in changing the results of paleodemographic research both qualitatively and quantitatively. Unfortunately, due to the nature of paleodemographic research it cannot be said of how effective the manifesto is.

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POPULATION FROM SOUTHEASTERN FLORIDA

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

CHAPTER ONE: INTRODUCTION

Estimating the population dynamics, such as mortality or sex ratios, of pre-historic societies is difficult to perform when little remains of the extinct culture. In many cases, the soils of the archaeological site will erode the cultural materials and cause extensive taphonomic damage to skeletal remains. This damage makes the analysis of pre-historic societies strenuous to decipher. Regardless of the difficulty associated with estimating the population dynamics, it is essential for understanding the cultural behavior of the society. Those who choose to examine these issues do so through the analysis of skeletal materials under the theoretical approach outlined in the field of paleodemography.

Paleodemography

Paleodemography is a study that attempts to define the demographic parameters of past populations by analysis of archaeological skeletal artifacts (Hoppa 2002). It is common for paleodemographic studies to attempt to derive the mortality rates of a past population by assessing the distribution of age-at-death estimations for individuals of a sample collection. In doing so they assert that the sample collection is a true representation of the past population. According to Howell (1986) if the population parameters are known, or can be estimated, the population structure is highly predictable and can be used to understand the population of the past, present, future for that particular group. However, many researchers (Petersen 1975; Howell 1976; Bocquet-Appel & Masset 1982, 1996) have argued the reliability and accuracy of paleodemographic studies, as there are quite a few assumptions built into the paleodemographic theory.

According to Hoppa (2002:9) there are two major assumptions made by the paleodemographic theory. Firstly, it is assumed that the age and sex estimations within the sample of dead individuals will provide a clear and accurate representation of the once-living population. Secondly, it is assumed that any bias that has the ability to affect the data can and will be recognized to later be taken into account. These assumptions do prove to be problematic as there are a few issues related to the methodologies used to determine the age and sex estimations. However, according to Howell (1976) these assumptions are not the only ones to be made by the paleodemographic theory.

Howell (1976) discusses the issue that demographic analysis relies on the assumptions of biological uniformitarianism. The biological uniformitarianism principle states "…that past and present regularities are crucial to future events and that, under similar characteristics, similar phenomena will have behaved in the past as they do in the present, and will do so in the future" (Hoppa 2002:10). The assumption asserts that the mortality processes were the same in the past as they are in present day. This can also prove problematic; in some cases there are observable differences in behavior between current populations and past populations, these ultimately affect mortality processes.

Regrettably, the theoretical assumptions of paleodemography are not the only issues of the field. While age-at-death estimations are a common practice for any trained osteologist, the methodologies tend to be severely limited in their ability to estimate the true chronological age of a deceased individual. This is a major concern for all age-at-death estimations and especially for paleodemographic researchers. A typical age-at-death estimation analyzes the physical traits of a set of remains to infer the biological age of the individual, while asserting that biological age is synonymous with their chronological age (Garvin *et al.* 2012; Kemkes-Grottenthaler 2002; Nawrocki 2010).

An individual's biological skeletal age, however, is not an accurate proxy for the chronological age researchers try to estimate. With a biological age estimation, an individual may exhibit skeletal morphological changes that are typically associated with younger or older individuals, due to variation or general degradation. This infers that an individual's biological age is the morphological appearance of key skeletal features associated with younger or older arbitrary systematic age sequences. On the other hand, chronological age it is simply meant to refer to an individual's age in years since the date of birth. It is possible for an osteologist to estimate an individual's biological age, but it is also possible that the biological age is not a representation of an individual's chronological age. Therefore this presents a problem, when most osteologists report an age estimate, it is typically meant to refer to the individual's chronological age.

The issue of using biological age as a proxy of chronological age however is not the only problem with age-at-death estimations. Age-at-death estimation methodologies are riddled with many points of concern where the reliability, accuracy, and validity of the methods are low. A major problem with age-at-death estimations is the likelihood of an age estimate to show signs of age mimicry (Boldsen *et al.* 2002). Age mimicry is a phenomenon that occurs when an osteologist uses an age-at-death estimation method to produce an estimate, but the estimate only mimics the reference sample that was used to create the method. As this is the design of the method, it does not seem to be an issue; however, when one considers the variability of morphological change caused by aging processes between populations, the reference sample may not be appropriate for the population one is studying. This is a common concern with frequently used methods, such as the Suchey-Brooks pubic symphysis method (Brooks & Suchey, 1990), the auricular surface scoring method (Lovejoy *et al*. 1985), and the scoring of the 4th rib (Íşcan *et al.* 1984).

While paleodemography is debated, the field is still incredibly useful for its analysis of skeletal remains to infer the behavior of past populations (Buikstra and Konigsberg 1985:316). As argued by Witter-Backofen (2008: 384) "the reconstruction of mortality patterns is of central interest… because survival patterns are fundamental to our understanding of the living conditions that human populations faced". Thus the field, while having issues with methodologies is still useful and necessary for the understanding of the past. Ultimately these issues have been addressed in previous publications which allude to the ramification of the central problems outlined (Hoppa and Vaupel 2002; Witter-Backofen 2008).

Rostock Manifesto

Due to the criticisms provided against paleodemographic studies, researchers who favor this branch of study created a workshop in 1999 with a follow-up meeting in 2000 to address the concerns with the field. The result of this meeting provided what is now known as the Rostock Manifesto (Hoppa & Vaupel 2002). The goal of the Rostock Manifesto was to address four concerns within the field of paleodemography. Firstly, to develop more reliable age indicators that reflects chronological age. Then, to develop methods to determine the probability, $\Pr(c|a)$, of observing a suite of skeletal characteristics c given known age a. Also, to state that in paleodemographic research, what is of true interest is the probability, $\Pr(a|c)$, that skeletal remains are certain age a given characteristic c and that $\Pr(c|a) \neq \Pr(a|c)$ while $\Pr(a|c)$ can only be calculated from $\Pr(c|a)$. Lastly, that the probability, $f(a)$, distribution of lifespans in the target population must be calculated first (Hoppa & Vaupel 2002). It is argued that through the correction of these concerns, paleodemographic studies will prove to be useful and accurate for understanding the dynamics of past populations.

According to Hoppa and Vaupel (2002) the Rostock Manifesto is the solution to the issues of paleodemography. With the manifesto as a guide, a researcher is able to conduct paleodemographic inquiry that is reliable and provide better represent the sample of the population being studied. In the same publication, many academics defined new methodologies that work in accordance with the Rostock approach with the same goal of reshaping the use of paleodemography (Boldsen *et al*. 2002; Holman *et al.* 2002; Love & Müller 2002; Wittwer-Backofen & Buba 2002; Wood *et al.* 2002). However, there is still more work that is necessary before one can assert the effectiveness of the Rostock Manifesto on the results of paleodemographic research.

Determination of Effectiveness for Rostock Manifesto

With the knowledge pertaining to the issues of the field of paleodemography, previous studies should be analyzed and adjusted using the appropriate measures addressed by the Rostock Manifesto. Such a case can be seen in the discussion of the paleodemographic parameters of the Highland Beach sample argued by Winland (1993). While Winland's thesis was focused around paleopathology, in his discussion of the paleodemographic parameters of the population he analyzed, he focuses on the methodologies for age-at-death estimation that are a major concern of fellow researchers. As his thesis was published prior to the publication of the Rostock Manifesto, it can be argued that his results of the population parameters should be evaluated against the age distribution calculated from new and more appropriate paleodemographic methods.

In the direct comparison of both studies, it can be argued that one can assert the effectiveness of the Rostock Manifesto. It is through this comparison that one would have the ability to state if the manifesto has changed the results of paleodemographic studies, therefore justifying the new guidelines of the field. Unfortunately, there are no known studies that directly compare previous and current paleodemographic research, however, the methods themselves have proven to be more accurate.

This thesis aims to assert the effectiveness of the Rostock Manifesto through the reevaluation of the demographic parameters of the Highland Beach sample. Through qualitative and quantitative analysis between both studies, it is possible to examine how using the techniques outlined in the Rostock approach reshapes the results granted from paleodemographic research. It is from these results that one can assert the validity of new paleodemographic research due to the strong methodologies used in correction of previous studies.

CHAPTER TWO: MATERIALS

Highland Beach (8PB11)

Located a little more than three miles north of the Boca Raton city limits, in southern Palm Beach County Florida, is the site of a pre-Columbian Native American society. According to Winland (1993, 2002), the site in question dates back to roughly 800-1,400 years ago associating this area with the Spanish River Complex and was inhabited during the Glades II to Glades III time periods (İşcan 1989). As discussed by Wheeler *et al.* "the Spanish River Complex… is one of the largest aboriginal localities in southern Florida…" (2002: 125). According to the information presented, it is known that the Highland Beach site (8PB11) is apart of the larger Eastern-Okeechobee culture area (Furey 1972; İşcan 1989; Winland 1993, 2002).

As argued by Winland (1993: 34), the Highland Beach burial mound (8PB11) is associated with two village sites. The following archaeological sites represent the first village in question: Boca Weir (8PB56), Boca Beekman (8PB55), Boca Snead (8PB58), and Boca Aylward (8PB57), while the Boca Midden (8PB12) is the second village site believed to have an association with the burial mound. As these sites and the Highland Beach burial mound are associated with the Spanish River complex, it is believed that the site belongs to the Jeaga tribe and not of the Calusa, Tequesta, or any other south Florida Native American population from the area (Winland 1993).

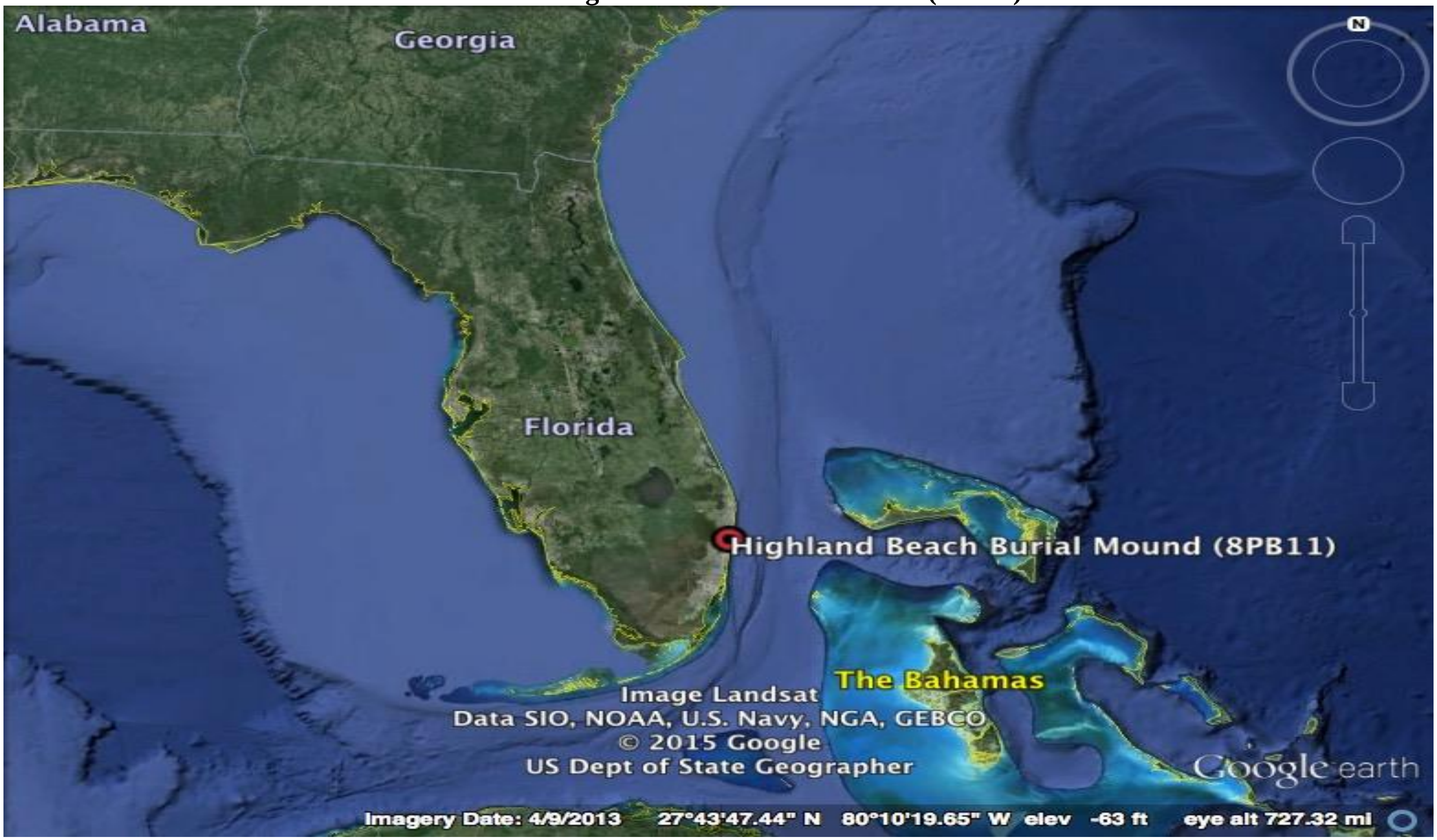
Winland (1993) later argued the reconstruction of environmental conditions of the population native to the Spanish River complex. As the site is within 200 meters of the Atlantic coast, it has been discussed that the subsistence strategy focuses heavily on marine life. However, Winland (1993) also explains that the local landscape was rich in floral and faunal diversity, which was used to substitute the regular diet. The cultural remains recovered from the Boca Midden (8PB12) also suggest a similar pattern, as argued by Winland (1993).

What remains of this site (8PB11) is now curated by the Department of Anthropology at Florida Atlantic University following the summer excavation of 1980 (Winland 1993). The majority of research performed on this sample attempts to define the population health from the examination of pathological conditions on multiple skeletal features (Isler *et al.* 1985; İşcan 1989; Winland 1993, 2002; Kessel 2001). Most commonly analyzed are the dental conditions of adult skeletons, in order to infer dietary behavior (Isler *et al.* 1985; İşcan 1989; Kessel 2001). Winland (1993, 2002), on the other hand, focused primarily on disease and population ecology derived from all skeletal materials. All studies found the sample derived from the burial mound of Highland Beach to be a relatively health population that practiced a maritime hunter-gatherer subsistence strategy heavy in protein consumption. Consequently, these researchers justify the high prevalence of elderly (>50 years old at time of death) individuals represented in the age-at-death distribution.

Also discussed by Winland (1993, 2002) is a brief outline of the demographic parameters for the Highland Beach sample. Winland asserts the impossible, although alluding to the unrealistic, value of the estimate for population density due to the nature of data utilized in paleodemography, by discussing the population size for this apparent Jeaga settlement (1993: 54-55). Winland (1993) also presents mortality and survivorship curves dependent on a life table analysis, illustrating the crude mortality rates indicative of the sample. His paleodemographic reconstruction supports the previously mentioned results, alluding to the ability of this population to practice a hunter-gatherer subsistence strategy.

Given the prehistoric archaeological context and the fragmentary nature of this collection, the Highland Beach sample would not be a first choice for paleodemographic research. As noted by many researchers, the field of Paleodemography is controversial to begin with, to have a sample that has no historical records and is a highly fragmented assemblage with no complete skeletons further complicates the analysis. However, with the recent discipline reformation and publication of the Restock Manifesto this sample can be used to reconstruct the population dynamics and provide insight on the prehistoric Native American population. As it were, there have been studies that have identified the demographic parameters of the Highland Beach sample.

Figure 2.1
Location of Highland Beach Burial Mound (8PB11)



The Highland Beach burial mound is located in southern Palm Beach county Florida in the township of Highland Beach.

CHAPTER THREE: METHODS

Sampling

Previous studies have discussed a minimum number of individuals (MNI) for this sample to be with a range from 100 to 150 individuals (İşcan 1989; Winland 1993, 2002; Kessel 2001), while the number of individuals recorded for this study exceeds the higher MNI estimate. The discrepancy in the number of individuals is likely caused by the high degree of taphonomic damage present on the remains and the degree of commingling associated with the secondary burials present in this mound. Unfortunately these conditions make osteological analysis difficult—especially for paleodemographic research.

Table 3.1
Determination of MNI and Sample for Highland Beach Collection

Sex Estimation	*Number of Individuals Identified*	*Number of Individuals with a Maximum Likelihood Age Estimate*
Male	65	58
Female	52	45
Ambiguous	13	13
Unknown	86	46
Total	**216**	**162**

The MNI of the Highland Beach collection and sample utilized as defined by this study. A total of 25% of the sample was rejected due to the inability to estimate age-at-death.

For this present research I have identified a total of 216 separate individuals residing in the Highland Beach Collection. Of the 216 individuals, 25% of the sample had to be rejected due to the strict confines of the age-at-death methods utilized and the high degree of taphonomic damage previously mentioned. Thus, it was possible to estimate age-at-death in only 162 of those individuals. From the 162 individuals the sex of each individual was also estimated. Though it was impossible to estimate sex for some individuals due to ambiguous or absent skeletal traits, all individuals were included to the sample pending their ability to receive an age-at-death estimate. The result of the sampling is displayed in table 3.1 above.

Age-at-Death Estimation

The essential function of this thesis is to utilize an age-at-death distribution to model mortality of the archaeological sample from site 8PB11; as a result, an age-at-death must be estimated for each individual of this sample. According to the Rostock approach, one must use appropriate methodologies that do not inherently rely on reference collections for comparative analysis. All adult skeletons (>15 years old at time of death) analyzed were estimated using transition analysis (Boldsen *et al.* 2002) while sub adults (<15 years old at time of death) were analyzed using multiple age-at-death methodologies.

Boldsen *et al.* (2002) in an attempt to solve the issues mentioned, has created a new age-at-death estimation method known as Transition Analysis. Transition analysis attempts to answer the concerns raised about age estimations by following the guidelines of the Rostock Manifesto. According to Boldsen *et al.* (2002), transition analysis allows an osteologist to be more reliable and accurate with age estimates across all ages as the structure of the method allows for a small sample to produce a general population age distribution. Once this is completed, an age estimate can be calculated so that it will not have issues of age mimicry. This method attempts to predict the probability function, $f(a)$, of age distribution in order to calculate the probability, $\Pr(a|c)$, of age, a, given a certain skeletal feature, c. It is the $\Pr(a|c)$ that an osteologist will use to infer as an individual's age-at-death estimate. With the method able to not rely solely on a reference sample, the age estimate provided will not be merely a reflection of the reference sample.

Transition analysis has more than one functional approach for deriving an age estimate. It is possible to estimate age-at-death of an individual using transition analysis from a one variable (single skeletal trait) or multivariable (multiple skeletal traits) calculation. Although it is possible to use only one skeletal trait for calculation of an age estimate, it has been argued (Bethard 2005; Kemkes-Grottenthaler 2002) that multivariable calculations results in better age estimates as it accounts for sequential age changes. With single trait estimation calculations, the estimate typically does not account for the many factors that influence an individual's senescent variation (Bethard 2005). Due to this reason, most researchers use transition analysis as a multivariable age estimate that incorporates the pubic symphysis, auricular surface and cranial sutures.

Using this method it seems it was possible to estimate age-at-death for all individuals, making the sample more reliable for estimating the population parameters. In a case where it was unclear as to which stage designation to a particular component of a feature should be assigned, the method is robust enough to calculate an age estimate with components that are scored in two stages. While if a component could not be observed, it was be coded as unscorable. In situations where an individual's age-at-death could not be estimated, I omitted the individual from the population age distribution analysis. This was only possible if the cranium and parts of the Os Coxae were missing from a set of skeletal remains. However, in most cases the age-at-death of an individual can be estimated with either a univariate or multivariate regression formula that follows the transitions of age progression (Boldsen *et al.* 2002).

Univariate regression analysis evaluates the degree of age similar to that of the common age-at-death estimation methodologies. In the same way that the Suchey-Brooks method treats the public symphysis as a single feature, with transition analyses involving a univariate approach, the pubic symphysis, auricular surface, or the cranium are considered to be single features (Boldsen *et al.* 2002). Boldsen and colleagues (2002:81-82) "…assume that the developmental trajectory for the trait can be broken down into an invariant sequences of *s* distinct, nonoverlapping stages, and that morphological change is strictly unidirectional with respect to those stages." It is later expressed that an individual progresses from stage *a* to stage *a+1* in sequential order without making jumps from stage *a* to stage *a+2*. It is possible to use a univariate regression formula to estimate the age-at-death of an individual using any one of these three features: pubic symphysis, auricular surface, or the cranium.

In a similar fashion to other age estimation methodologies, the pubic symphysis is scored to identify the sequential age changes of an individual. Unlike the Todd (1920), McKern and Stewart (1957) and Suchey-Brooks (1990) methods, transition analysis evaluates the pubic symphysis in five components (Boldsen *et al.* 2002): symphyseal relief, symphyseal texture, superior apex, ventral symphyseal margin, and the dorsal symphyseal margin. Components are scored on varying scales of age related progression for each component separately. As the pubic symphysis is a paired feature, it is noted that observers should evaluate the pubic symphyses of both the left and right side of each individual, as there are differences between them.

The auricular surface of the sacroiliac joint of the ilium is another feature analyzed to produce an age estimate with transition analysis. Similar to the pubic symphysis, the auricular surface is broken into a couple of components (Boldsen *et al.* 2002): surface topography (both superior and inferior), surface morphology (superior, apical, and inferior), inferior surface texture, and exostoses on the posterior ilium (evaluated as a whole, superior, and inferior). Once again, each separate component has its own scoring scales specific to the component, and the observer should record both left and right-sided auricular surfaces.

The last feature to be examined by transition analysis to produce an age-at-death estimation for an individual is the cranium. Boldsen *et al.* (2002) discusses that it is important to include cranial suture stenosis as in archaeological assemblages it is common to recover an individual's cranium rather than the os coxae. A researcher using transition analysis should observe the ectocranial suture closure of an individual as the specific areas noted to analyses contain useful age identifiers. Unlike the pubic symphysis and auricular surface, the scoring of all components of the cranium (coronal pterica, sagittal obelica, lambdoidal asterica, zygomaticomaxillary suture, and the interpalatine suture structure) has the same stage distinctions.

Although the univariate regression formula is capable of estimating age-at-death for an individual, when possible it is argued to use a multivariate regression analysis of the individual to produce an age estimate (Boldsen *et al.* 2002; Bethard 2005). Instead of examining one feature and deriving an age estimate, the multivariate approach includes all three features mentioned. When in combination with each other, the components of the three features creates a regression formula that is more robust in its ability to produce the likelihood probability of an individual being a certain age given the plethora of characteristics scored. In terms of paleodemographic research, the multivariate regression analysis allows for the age estimate to be a representation of the population and individual belongs to rather than the reference sample used to create the age-at-death estimation methodology.

Although transition analysis works for adult remains, the method is incapable of estimating and skeleton that has not reached puberty. Due to this reason it is important to adapt a policy of accepting other age-at-death estimation methodologies when examining individuals that clearly span sub-adult and adult age cohorts. For the purpose of this study age-at-death estimations for sub-adult skeletons were completed using dental eruption patterns, cranial bone dimensions, as well as long bone length.

Dental eruption patterns are highly predictable and uniform across known populations. In comparison to many other age-at-death estimation methodologies, such as most adult age estimations, dental eruption patterns are very reliable and accurate to the age of an individual at the time of their death. However, there is a limit to this estimation methodology. This method only works when there are teeth present in a forensic or archaeological context and when the individual is younger than 23 years in age at the time of death. To estimate the age-at-death of an individual using the dental eruption pattern I compared the dental development to the London Atlas published by Dr.

AlQahtani in 2010. This method was only used on individuals who have not entered puberty, as transition analysis would then take preference. Dental eruption is a useful method, however in some cases dentition was not recovered for any number of reasons.

In the case of fetal remains, individuals that are in the age cohort of 8 weeks inter-uterine development to birth (Scheuer and Black 2004), other age-at-death estimation methods must be utilized. As dental remains are extraordinarily rare for fetal remains, the cusps of teeth are only just forming in the mandible around 30 weeks in-utero, it was not possible to use dental eruption patterns. To use reliable age-at-death estimations I referred to the dimensions of two cranial elements—pars petrosa of the temporal and pars basilaris of the occipital. As presented by Scheuer and Black (2004) the length and width of both skeletal elements are independent age indicators for fetal development from 12 weeks in-utero to birth (40 weeks in-utero).

Similarly, Scheuer and Black (2004) have also presented an age-at-death estimation for fetal remains dependent on long bone measurements. Although this was less common than the other method presented on the dimensions of the pars petrosa and pars basilaris, determining the age-at-death of the fetal remains was possible through the examination of long bone length and width. Similarly this method also determined age of a fetal individual from 12 weeks in-utero till birth.

ADBOU

My preferred regression analysis for age estimation is the multivariate approach; however, in cases when a multivariate regression could not be performed I have used the univariate regression approach. To perform the necessary calculations, I have collected the scoring data for each component of each individual on the data collection sheet I created. Once the scoring data was collected for both age-at-death and sex, I input the data into the ADBOU software for analysis and calculation.

ADBOU is a software program authored by Dr. Jasper Boldsen in association with the Anthropological Database at Odense University in Denmark (Bethard 2005). This software program was created for use with estimating age-at-death when researchers use the transition analysis method published by Boldsen *et al*. (2002). This program was created for researchers to input the raw data collected from scoring the skeletal features, and runs it against the known population's age distribution function $f(a)$. In cases, such as with the Highland Beach population, when the population's age distribution is unknown the researcher inputs statistical hazards for calculation of an individual's age-at-death.

Due to the nature of the collection I am working with, I have determined to select the archaeological hazard suggested by Boldsen *et al*. (2002). Although the software program's archaeological hazard option is based on 17th century Danish parish records, the other option is a forensic hazard based on recent cases. Due to the provenience of the data collected from this study, it proved evident that I should use the archaeological hazard over the forensic hazard. Transition analysis, through the use of ADBOU, gives me confidence in the age-at-death estimations produced for individuals. The estimates will represent the individual's biological skeletal age without relying on age estimation methodologies that produce age mimicry.

When data is input in the program, and the program is ran, the output of the program is a numerical "probability that death occurred at each possible age" (Boldsen *et* *al*. 2002:93) with a graphical aid to illustrate the probability of an age given the characteristics measured $\Pr(a|c)$ (Bethard 2005). According to Bethard (2005:31), the graphical output is represented in five distribution curves depicting the "age estimates for aggregated morphological complexes… and individual age indicators." From this output I have safely estimated an individual's age-at-death while utilizing the maximum likelihood estimate, this is important for the generation of an age-at-death curve per individual.

Sex Estimation

Unlike age-at-death estimations, estimation of the sex of an individual is relatively reliable. Although there is variation among populations in terms of sexual dimorphism, the general pattern for sex differences between males and females are predictable. Men are typically more robust and females are more gracile, however, this usually applies to cranial features and obscure pelvic features. Thus I found it imperative to examine multiple skeletal features of adult individuals; sexually dimorphic characters in sub-adults are not reliable enough to insure great confidence in sex estimations.

Although there are many sex estimation methodologies for skeletal remains, I have only focused on sex estimation techniques that pertain to the os coxae and cranium. As the transition analysis age-at-death estimation methodology examines the os coxae and the cranium exclusively, I think it is important to focus the sex estimation methodologies on the skeletal locations that are already being studied. For each skeletal location I have used prominent sex estimation methods.

To determine the sex of an individual I have used the Phenice method (1969), which estimates sex of an individual from the os coxae. This sex estimation technique focuses on three features found on the pubic bone of the os coxae. To estimate sex, I scored the presence or absence of a ventral arc on the ventral surface of the pubis, the concave or convex nature of the ischiopubic ramus, as well as the width of the ischiopubic ramus. In the case where the pubis was not recovered and sex estimation cannot be produced, I have evaluated the sex of an individual by scoring the greater sciatic notch of the os coxae.

In terms of the cranium, I obtained sex estimations for individuals using the methods illustrated in the Standards Manual by Buikstra and Ubelaker (1994). The Standards Manual discusses the sexing methodology by Ascádi and Nemeskéri (1970) by scoring the features of the cranium. This technique evaluates the sex of an individual through analysis of the nuchal crest of the occipital bone, the mastoid processes of the temporal bones, the supraorbital margin and ridge of the frontal bone, as well as the mental eminence of the mandible. Each feature is scored from 1 to 5 with a score of 1 equates to hyperfeminine and a score of 5 equates to hypermasculine (White *et al.* 2012).

Demographic Modeling

While demographic modeling is essential for this thesis, many methodologies are inappropriate for this type of data. It was the standard practice to use life table analysis, because it shows a great deal of reliability and accuracy for the calculation of many demographic parameters. Unfortunately, with data derived through skeletal examination this type of analysis is considered unsuitable. For this reason, I have employed other means to model the demographic parameters necessary for this type of research.

Once I collected all the age-at-death and sex estimations, I calculated the frequency of age-at-death for all 162 individuals included in this study. I used five-year age cohorts to assert the frequency of individuals who have died in that age range. While Wood *et al.* (2002) argues the frequency distribution of the age-at-death for all sampled individuals is inappropriate for societies that are not stationary, in order to statistically compare Winland's data to this current study, modeling the frequency data become necessary. Thus I have established a frequency distribution using the histogram function in excel.

To correctly model mortality using paleodemographic samples it is important to use statistical hazard models. Such a model is only possible if one assumes that a population is stable, which is less restrictive than the assumption of a stationary population. Wood *et al*. (2002:135-136) explains this principle as "weak ergodicity", it allows for the modeling of demographic parameters from stable populations when the model typically fits. Should there be a dramatic increase or decrease of population size, the Gompertz law of Mortality parametric model can be used.

The Gompertz model is the earliest know attempt of deriving a parametric model of mortality (Wood *et al.* 2002:145). The Gompertz model of mortality attempts to identify the force of mortality with the utilization of two estimated parameters related to age senescent risk of death. However, the Gompertz model of mortality is not the only acceptable method for modeling mortality. Many have argued for the use of the Gompertz-Makeham model of mortality, this adds an age-independent risk as an additive parameter. While the Gompertz-Makeham model seems more appropriate, it rarely produces significantly different results (Milner *et al.* 2012; Wood *et al.* 2002). Wilson (2014) argues that models that have two or three parameters are more effective in demographic studies utilize skeletal materials. For analysis this model presents the force of mortality $\mu(a)$ as

$$\mu(a) = \alpha e^{\beta\alpha}. \tag{3.1}$$

This model also presents the probability density function (PDF) as

$$f_0(a) = \alpha \exp\left[\beta\alpha + \frac{\chi}{\beta} \quad \left(1 - e^{\beta\alpha}\right)\right]. \tag{3.2}$$

Also discussed by Wood *et al.* (2002) is the survival function known as

$$S(t) = \exp\left[\frac{\alpha}{\beta}\left(1 - e^{\beta\alpha}\right)\right]. \tag{3.3}$$

With these functions it is possible to model the mortality of the sample in question.

To model the mortality of the Highland Beach sample I used the statistical program R. First, it was important to estimate the parameters given the sample for this study. To do this, I adapted Dr. Konigsberg's (2003) lecture of demographic anthropology to format an appropriate function for the equations 3.1 and 3.3, in order to find the log-likelihood estimate of the Highland Beach sample. Once completed, I was then able to plot the Gompertz mortality and survivorship curves that are necessary for paleodemographic research. The renderings of this model were computed in the statistical program R to later be input into the results chapter of this thesis.

Comparative Analysis

To finally assert the effectiveness of the Rostock Manifesto I had to compare the two studies, Winland (1993) and this current study. Unfortunately, due to the time Winland's thesis was written, his methods did not follow the Rostock approach. Therefore, it is necessary to compare his results with the results of a study that followed the corrected methods on the same sample. Also, Winland did not publish his data set nor was he contactable to receive his age and sex data. This left little options for statistical testing, yet both studies needed to be compared. As a result, I fount it necessary to compare the both studies qualitatively and quantitatively.

Qualitative analysis primarily focused on the overall product of both studies; I compared what knowledge was gained from each study and how it was presented. Unfortunately, as is the nature of the Rostock approach, this qualitative comparison will show a distinct difference; the new methods produce different formats to the results of paleodemographic research. Through my quantitative analysis, I am able to show if both studies are statistically different from one another.

To perform quantitative analysis I relied on a Chi-square test for testing independence of the frequency distributions provided from Winland's thesis (1993) and this current study. I set my null hypothesis to be Winland's age-at-death frequency distribution while the statistical test measures it against the frequency distribution of the current study. Through the probability of the chi-square test I was able to reject or accept the null hypothesis of having equal frequency distribution. With the rejection or acceptance of the null hypothesis I was able to assert the effectiveness of the Rostock Manifesto.

CHAPTER FOUR: RESULTS

As discussed previously, the sample size of this study exceeds the sample size of Winland's thesis (1993). As exemplified by table 4.1, this study lists a sample size of 162 individuals, compared to Winland, who discussed a sample size of only 128 individuals. Also notable between both studies is the ratio between males and females, which is similar. Winland (1993: 39) notes a sex ratio, derived by the function:

$$\frac{Number\ of\ males}{Number\ of\ females}. \tag{4.1}$$

Thus, the male to female ratio Winland discusses is 1.19/1.00 while this study has a ratio of 1.28/1.00. Although there is an increase in sample size identified in this study, the proportions of males to females are roughly the same while the major increase of individuals can be found in the new category listed in this study of ambiguous individuals. While this is not the most significant aspect of this study, it is possible that the newly identified individuals in this study can cause a difference in frequencies for age cohorts.

Table 4.1
Sex-specific Sampling of the Highland Beach Collection

		Winland	Hennessey
Males	n=	50	58
Females	n=	42	45
Subadults	n=	35	41
Ambiguous	n=	0	13
Unknown	n=	1	5
total		**124**	**162**

The Comparative sex specific frequencies of individuals between Winland's thesis (1993) and this current study are outlined. Also included is the number of individuals utilized in both studies.

Age-at-Death Frequency Distribution

The argument made by Wood *et al.* (2002) states that frequency distributions would be an accurate representation of the mortality of a society if that population was considered stationary. Stationary populations would then have to assume "…the population was closed to migration and had an intrinsic rate of increase equal to zero, age-specific schedules of fertility and mortality that were unchanging over time, and an equilibrium age distribution induced by age-specific birth and death rates" (Wood *et al.* 2002: 130). It can be argued that this is never the case with realistic populations and certainly not for archaeological samples of extinct populations. While an age-at-death frequency distribution is not equal to the Pr(a) that is desired by paleodemographic research, it was necessary to calculate due to Winland's thesis (1993). In his thesis, Winland only published his frequency data, as opposed to the actual age-at-death estimations.

As exemplified in table 3, the frequency data provided by Winland (1993) and this study is presented in age cohorts equal to five year intervals. There are 19 age cohorts associated with this sample which range from fetal development to 85 years in age. As there were no maximum likelihood age-at-death estimates that exceeded 85 years in age, those ages were excluded from the frequency age cohorts. Common with human mortality curves (Wood *et al.* 2002: 137), it is noticeable a similar pattern to the frequency distribution presented from this study as there are increased amounts of individuals within fetal development and older individuals.

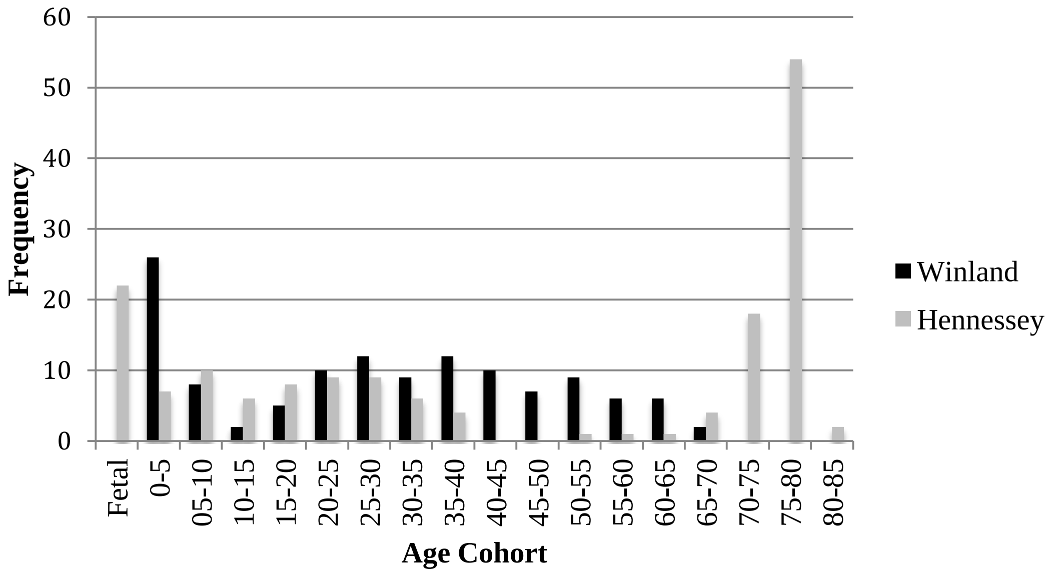
In contrast to Winland's frequency distribution (1993), there is a prominent difference between the fetal remains and older individuals as presented in table 4.2. It is clearly observed in Winland's study that the age-at-death estimations do not exceed 70 years in age, while in this current study, the highest frequency and percentage of individuals in a single age cohort exists in the 75-80 years of age at time of death. Also evident is the second highest frequency and percentage of individuals in a single cohort, which belongs to the fetal developmental stage; to which Winland does not recognize in his analysis.

Table 4.2
Age-at-Death Frequency Distribution

	Winland		Hennessey	
Age	#	%	#	%
Fetal	0	0	22	13.58
0 - 5	26	20.97	7	4.32
05 - 10	8	6.45	10	6.17
10 - 15	2	1.61	6	3.7
15 - 20	5	4.03	8	4.94
20 - 25	10	8.06	9	5.56
25 - 30	12	9.68	9	5.56
30 - 35	9	7.26	6	3.7
35 - 40	12	9.68	4	2.47
40 - 45	10	8.06	0	0
45 - 50	7	5.64	0	0
50 - 55	9	7.26	1	0.62
55 - 60	6	4.84	1	0.62
60 - 65	6	4.84	1	0.62
65 - 70	2	1.62	4	2.47
70 - 75	0	0	18	11.11
75 - 80	0	0	54	33.33
80 - 85	0	0	2	1.23
total	**124**	**100%**	**162**	**100%**

Included in this table are the frequency distributions presented by both Winland's thesis (1993) and this current study. Also included are the percentages of the frequency for of the age cohort for the entire sample.

Figure 4.1
Comparative Age-at-Death Frequency Distribution

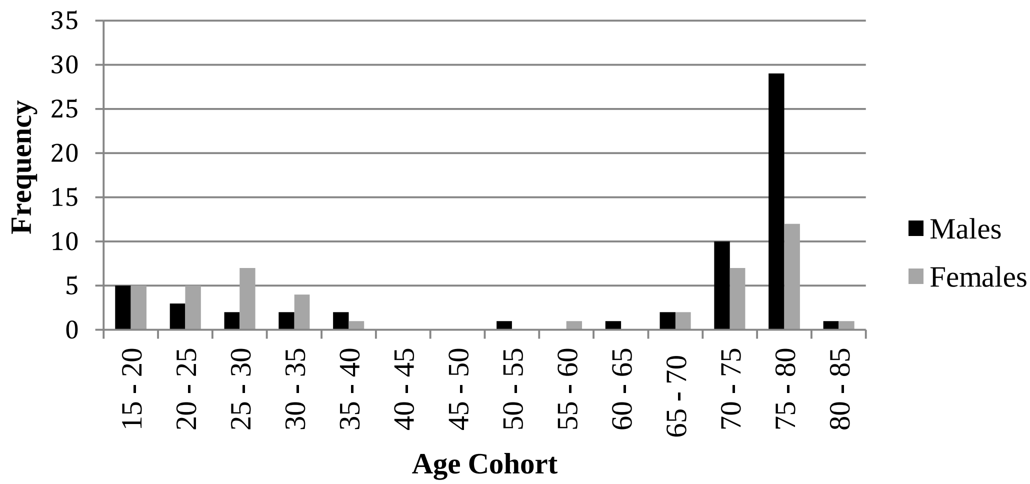


Bar graph of the comparative age-at-death frequency distributions for both Winland's (1993) data and this current study completed by Hennessey.

While figure 4.1 presents a combined age-at-death frequency distribution for males and females discussed by Winland (1993; 2002) and this current study, the distribution of age-at-death within a population is typically specific to sex. The Highland Beach sample is no different. As previously discussed, the ratio of males to females for this sample is 1.28/1.00, the distribution of age-at-death is also remarkably different from one another as exemplified in figure 4.2. For many societies, having sex specific mortality rates is quite common, seeing a difference in sex is expected.

Although the sex specific age-at-death frequency distribution is visually different, both sub-samples of the Highland Beach sample are also statistically different from one another. Using a Mann-Whitney *U*-test this current study was able to test the male and female age-at-death estimates in order to prove a statistical significance between the two sub-samples. The probability of having equal medians between both samples generated from the *U*-test equaled (p=0.0050133). Therefore, I was able to reject the premise of having equal medians between both sub-samples, alluding to the sex specific nature of mortality between males and females.

Figure 4.2
Male and Female Age-at-Death Frequency Distribution



Bar graph of the age-at-death frequency distribution differences between male and female sub-samples of the Highland Beach collection completed by this current study.

Table 4.3
Mann-Whitney *U*-test for Equal Medians

Test for Equal Medians		
	Male	*Female*
Number of Individuals	58	45
Mean Rank	33.383	18.617
p (same med.)		0.0050133

A probability equal to 0.0050133 of equal medians between both male and female sub-samples proves a statistical sex specific mortality distinction for the Highland beach sample.

Demographic Modeling Using Appropriate Functions

With paleodemographic results no longer being presented in life tables and rarely in frequency distributions, it is important to take the appropriate measures to properly present the results from this study. To do this, graphical representation of both mortality and survivorship curves were generated in the free statistical software R. In order to draw both curves, it was necessary to first estimate the unknown parameters of the equation 3.1 (listed in chapter three of this thesis). As mentioned in the previous chapter, parameter estimation was possible through the log-likelihood estimation method also preformed in R. The results of this test are presented in table 4.4.

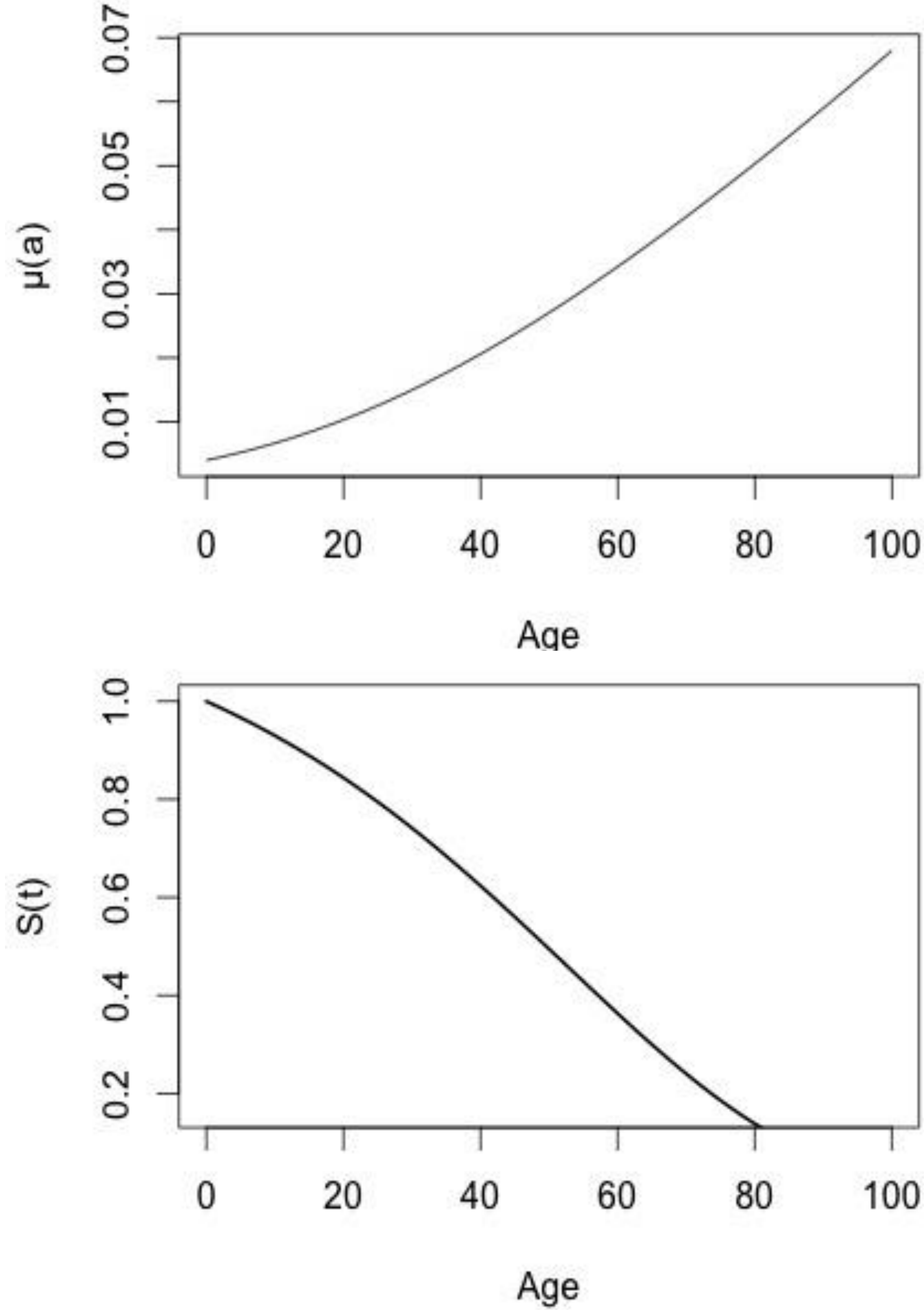
Table 4.4
Values of Estimated Parameters for Gompertz Model

	Estimated Parameters	
	a3	b3
Gompertz Model	0.00625109	0.02900833

Both parameters presented represent the senescent changes in mortality and survivorship for the Highland Beach sample.

Using the parameters outlined in table 4.4, it was possible to model both the mortality and survivorship curves for the Highland Beach sample. To use a more represented model, the complete age-at-death sample was utilized in the calculations. As presented in figure 4.3, the mortality curve of the sample agrees with typical mortality schedules common in most populations. Depicted in the curve, as the individual in the sample grows older there is an exponentially increasing force of mortality ($\mu(a)$) acting on them.

Figure 4.3
Senescent Changes in Mortality and Survivorship



The Gompertz curves for the force of mortality $\mu(a)$ and survivorship S(t) generated from R.

Survivorship, in opposition to the force of mortality, has an exponentially decreasing probability with increasing age. This is also typical and highly expected for demographic models. As presented in figure 4.4, as an individual begins life at birth the probability of surviving to the next age cohort is high, approaching p=1.0, while as an individual approaches the age of 80 years at the time of death (t=80) the probability of surviving approaches zero. This would mean, as there is an increase in the force of mortality there is a direct correlation to the decrease in the chance of surviving to a certain age.

While researchers (Wood *et al*. 2002) would argue that human mortality and survivorship are more complex then presented, the effect of using other mortality models that include more complex equations is slight. It can also be discussed that due to the nature of paleodemographic data, the ability to utilize more complex modeling function becomes hazier in its approach. Such functions are the Gompertz-Makeham and Siler models of mortality. Both of the models add supplementary parameters to illustrate the complex nature of the early mortality schedule for juvenile individuals, however, in this case deriving juvenile mortality rates was not possible. As a result, I argue the use of the Gompertz model to illustrate mortality and survivorship for the Highland Beach sample.

Effectiveness of the Rostock Manifesto

The comparative analysis between Winland's thesis (1993) and this current study is the most essential aspect to this thesis. As mentioned before, it was impossible to compare Winland's individual age-at-death estimates because the data he presents in his thesis (1993) and published article (2002) is formatted into frequency distributions. For the sake of comparison between both studies, it was necessary to compare the frequency data acquired to test the effectiveness of the Rostock Manifesto.

As mentioned previously, qualitative analysis of both studies has shown there to be a significant difference. However, this difference is the result of the abandonment of previous methods for new methods that produce results in a completely different format. As an example, it is no longer adequate to calculate life tables for paleodemographic research because the nature of the data is inappropriate for the commonly used method. Instead, it is now important to model the paleodemographic data using a suite of statistical hazard models, such as the Gompertz model of mortality. This change in methods has caused a significant change in how paleodemographic results are presented to the ivory tower of academia, as exemplified in figure 4.3.

As this is the case, with a qualitative review of the changed results of paleodemographic research due to the Rostock Manifesto, I argue that it is paramount to test the manifesto in a quantitative approach. As outlined in chapter three of this thesis, quantitative analysis of the Rostock Manifesto is possible if we compare studies performed on the same sample using both the anachronous methods, prior to 2002, and more modern methods outlined in the publication *Paleodemography: Age Distributions from Skeletal Samples* in 2002. However, because the data sets would not be compatible, it is important to follow a similar data format for both studies.

Since this is the case with Winland's analysis of the Highland Beach sample and this current study, I compared the age-at-death frequency distributions presented in table 4.2. To compare both studies, a chi-square test for independence was utilized, while setting Winland's (2002) distribution as the null hypothesis. Through this, I was able to test if there was a statistical significance in the two age-at-death frequency distributions.

Table 4.5
Chi-Square Test of Independence Between Winland and Hennessey

X^2 Test of Independence	
Winland	N=124
Hennessey	N=162
df	17
X^2	143.63
p(same):	4.29E-22
Monte Carlo p(same):	0.0001

The probability (p=4.29E-22) presented from the chi-square test of independence indicates a statistical significant difference between the two age-at-death frequency distributions.

As presented in table 4.5, the probability of having have similar age-at-death frequency distributions for both Winland (1993; 2002) and this current study was equal to p=4.29E-22. This probability allows me to reject the null hypothesis, which states, this current study has a similar age-at-death frequency distribution as Winland's (1993; 2002). Therefore, there is statistically significant difference between both studies. This simple statistic allows me to asset that the Rostock Manifesto, at the very least, was quantitatively effective in changing the results of paleodemographic research.

CHAPTER FIVE: CONCLUSION

With the recent changes to the approach to paleodemographic studies, it is important to examine the effect changes have on the results of such studies. However, there have been little to no studies that discuss whether the new changes, made at the Max Planck Institute for Demographic Research (MPIDR) convention in Rostock, Germany, are effective in at least changing the results from earlier studies to more contemporary research. Thus, I have argued the need to test the new methods against the previously utilized methods prior to the Rostock Manifesto by comparing the results of both studies on the same archaeological sample.

Rostock Manifesto is Effective

As previously discussed in chapter four of this thesis, the Rostock Manifesto is effective in changing the results of paleodemographic research. Through the examination of Winland's thesis (1993) and later published article (2002), I have compared his results of the Highland Beach sample to this study, which uses the new methods outlined the instrumental volume, *Paleodemography: Age Distributions from Skeletal Samples* (2002). Using the methods argued by the contributing academics (Boldsen *et al.* 2002; Herrmann & Konigsberg 2002;

Konigsberg & Herrmann 2002; Wood *et al.* 2002) it was possible to reexamine the demographic parameters of the archaeological sample to then qualitatively and quantitative compare the results.

As expected, the qualitative analysis between both studies is overwhelmingly anticlimactic. It comes to no surprise that there is a significant difference of how the results of paleodemographic research are presented to the academic world. We have disbanded the life table approach and turns towards appropriate statistical models, such as the Gompertz law of mortality. While this does not seem significant, it does allow for researchers to follow the trends between populations, in terms of mortality and survivorship, and compare the relative consistency. Also these statistical models are a better representation of the data collected from paleodemographic research.

The more significant results from this study can be seen in the quantitative analysis between both Winland's (1993) study and this thesis. Using a chi-square test for independence (table 4.5), assuming Winland's age-at-death frequency distribution as the null hypothesis, it was possible to illustrate a statistical significance between both studies. The probability associated with this test was found to be (p=4.29E-22), thus noting the difference. With quantitative analysis it is possible to assert that the Rostock Manifesto is effective for reshaping the results of paleodemographic research.

Ultimately the significance of this thesis is to stress the effective change in the quantitative analysis and the ability to compare these results with previous results on the effectiveness of the specific methods. As discussed by Boldsen *et al.* (2002) and Bethard (2005), transition analysis is a better-suited age-at-death estimation methodology when compared to more frequently used methods. It is imperative to assert that with the increase in accuracy and reliability of age-at-death estimate methodologies and mortality modeling, the results from this study illustrate that change in results of paleodemographic research has refined the field.

Possible Bias

While the results of this thesis are conclusive, the question can and should be raised as to how accurate these findings are. There are several valid arguments that can be made, for instance, the sample sizes utilized by both studies are not equal. Also, there may be a slight bias towards older individuals, due to the using a method that relies on forming age-at-death estimates drive from cranial suture stenosis. While it is important to note the possible bias of these results, these biases should not discredit the crucial findings reported.

As mentioned briefly, there is a discrepancy in sample size between Winland's thesis (1993) and this current study. It is unfortunate that there is not a reliable MNI reported for this archaeological sample, many have argued that the MNI to exist anywhere between 120 to 150 individuals (Isler & Íşcan 1985; Kessel 2001; Wheeler 2002; Winland 1993). Of this MNI, Winland (1993; 2002) discusses a sample size of only 124 individuals, noted in table 4.2 of this thesis, while I have sample 162 individuals. It is unclear the sample method proposed by Winland since it is not discussed in his methodology. It is likely he neglected to include the majority of the fetal remains present. The question remains, does the sample size effect the frequency distribution and the chi-square statistic?

While there is a clear difference in the number of individuals sampled for both studies, I argue that this does not fundamentally alter the significant difference in age-at-death frequency per age cohort. In most age categories, there is a significant difference in frequency between Winland's thesis (1993) and this current study. These differences are not a direct result of sampling differences, but rather, of utilizing various age-at-death estimation methodologies. As noted in table 4.2, there is a shift towards older individuals, made possible by using transition analysis for age-at-death estimation. Using transition analysis it is possible to estimate the age-at-death of an individual beyond 60 years in age more reliably and accurately to the individual's actual age at the time of their death (Boldsen *et al.* 2002; Bethard, 2005).

Transition analysis allows for a researcher to estimate the age-at-death of an individual who is beyond 60 years old, as a result, there is a reliance on cranial suture stenosis is a reliable age indicator. It is well known that cranial suture stenosis as a proxy for age-at-death estimation is not highly regarded in forensic or archaeological cases, due to the high level of variation between individuals and populations. As argued by Garvin and Passalacqua (2012), cranial sutures were ranked the lowest for adult age-at-death estimation methodologies among forensic anthropologists and bioarchaeologists. However, there are plenty of published works (Boldsen *et al.* 2002; Bethard 2005, Milner *et al.* 2012) that discuss the validity of using cranial suture stenosis in transition analysis.

In the case with the Highland Beach sample, individuals were highly fragmented and had clear signs of commingling. While sorting through the commingled remains was relatively easy, using pair matching methods and crude unpublished site maps from the 1980 excavation to sort individuals provided many difficulties. In addition, fragmentation of the remains made it difficult to utilize preferred skeletal features. As illustrated in table 5.1, the native soils also made it difficult to utilize the preferred skeletal elements for age-at-death estimation. Crania was the most utilized skeletal feature, due to the presence of intact crania, however, when possible all elements were used for age-at-death estimation.

Table 5.1
Frequency of Skeletal Features

Presence of Skeletal Features	
Crania	98
Pubic Symphysis	9
Auricular Surface	52

This table represents the frequency of skeletal elements able to be utilized in estimating age-at-death of an individual for the Highland Beach sample. Overwhelmingly, crania were the most resourceful age estimator due to preservation of skeletal materials in sandy soils.

Future Research

The results of this thesis allow academics to state that the Rostock Manifesto is effective in changing the qualitative and quantitative results of paleodemographic research. However, a major question still remains. How effective is the Rostock Manifesto, and how accurate are these results to known age mortality and survivorship schedules? While it is impossible for this thesis to answer the current question of the effectiveness of the Rostock Manifesto, these results are a stepping-stone for future research in the field of paleodemography.

For future research it would be advised to commit a paleodemographic study utilizing methods prior to and after the Rostock Manifesto, on known aged individuals, to answer the previously mentioned question. If research similar to this thesis is performed on known aged individuals, it will be possible to see how effective the Rostock Manifesto is in changing the results of paleodemographic research, in comparison with research using older methodologies. It is important to examine the effectiveness of the Rostock Manifesto; it can later then be used as a proxy for judging the reliability and accuracy of paleodemographic research.

For future research and possible PhD dissertation work, I propose examination of the changes in results due to utilizing the suites of methods associated with cultural demography, historical demography, and paleodemography. As it is the goal of paleodemography to provide similar results obtained by cultural and historical demography, research should be done examining the relationships between these fields and the applications of each for deriving the population parameters. Once this is completed, it will possible to examine the changes in population dynamics through time using all three sub-disciplines.

APPENDIX A:

R FUNCTIONS DERIVED FROM KONIGSBERG (2003)

```
>gompertz <- function (x, t=combinedsample[[1]])
>{
+		a3<-x[1]
+		b3<-x[2]
+		shift<-0
+		h.t<-a3*exp(b3*(t-shift))
+		S.t<-exp(a3/b3*(1-exp(b3*(t-shift))))
+		return(S.t*h.t)
>}
>gompertz2 <-function (x)
>{
+		lnlk<-sum(log(gompertz(x,combinedsample[[1]])))
+		return(lnlk)
>}
>optim(c(.01,.01),gompertz2,control=list(fnscale=-1))
>gompertz3 <-function (t)
>{
+		a3<-0.00625109
+		b3<-0.02900833
+		shift<-0
+		h.t<-a3*exp(b3*(t-shift))
+		S.t<-exp(a3/b3*(1-exp(b3*(t-shift))))
+		return(S.t)
>}
>gompertz4 <-function (t)
>{
+		a3<-0.00625109
+		b3<-0.02900833
+		shift<-0
+		h.t<-a3*exp(b3*(t-shift))
+		S.t<-exp(a3/b3*(1-exp(b3*(t-shift))))
+		return(h.t)
>}
>lines(0:80,gompertz3(0:80), col='black', lwd=2)
>lines(0:80,gompertz4(0:80), col='black', lwd=2)
```

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