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A Demographic Analysis of Skeletons from the Larson Site (39WW2), Walworth County, South Dakota

Douglas William Owsley
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Douglas William Owsley entitled "A Demographic Analysis of Skeletons from the Larson Site (39WW2), Walworth County, South Dakota." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

William M. Bass, Major Professor

We have read this thesis and recommend its acceptance:

Richard L. Jantz, Fred H. Smith

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

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"Thanks Dr. Bass
your time and interest
made this possible.
Doug

A DEMOGRAPHIC ANALYSIS OF SKELETONS FROM THE LARSON SITE (39WW2) WALWORTH COUNTY, SOUTH DAKOTA

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee

Douglas William Owsley

December 1975

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ABSTRACT

Paleodemographic analysis of 706 skeletons recovered from the Larson site (39WW2), Walworth County, South Dakota, is presented. The site was a protohistoric Arikara village and cemetery dating to approximately A.D. 1750-1781. Major objectives of this study were to reconstruct vital statistics of the Larson population and to determine population size of the village which contributed to the cemetery.

Analysis was accomplished using a life table methodology assuming a stationary population model. Vital statistics examined include data on mortality, survivorship, age-specific probability of death, life expectancy, and crude mortality rates. Interpopulation comparisons were made with other American Indian and world populations to determine differences unique to the Larson mortality profile. Causes of death are examined using available historical information and results from paleopathological analysis. Demographic data are applied to test a hypothesis that village abandonment was caused by a smallpox epidemic of 1780-1781. An attempt was made to identify areas of the cemetery which contain burials caused by this epidemic. Vital statistics reevaluated with elimination of these epidemic skeletal deposits allow assessment of the distortion in life table values produced by the inclusion of epidemic-related mortality.

Results indicate that the population had an extremely high infant mortality rate which remained fairly high throughout childhood. Adolescents enjoyed good health, having the lowest probability of death of all age categories. Mortality increased for young adults,

ages 15-19, particularly for females. A second major mode in the female mortality curve is at ages 35-39. The greatest percentage of male deaths occurred in the fourth decade, especially ages 30-34. Only 1.9 percent of the population attained an age greater than 55 years.

Crude death rate of the Larson population equaled 70 per thousand per year. This estimate is in accord with archaeological and historical sources which report a rapid Arikara population decline during the Post-Contact period. Causes of death included famine, intertribal warfare, childbirth and obstetrical care, and disease, especially tuberculosis and smallpox.

Demographic data supports the hypothesis that the population was infected by smallpox and that error from the normal population vital statistics is caused by the inclusion of epidemic-produced mortality. However, the quantitative changes observed are not dramatic and indicate that large skeletal samples mask the appearance of brief fluctuations in mortality rates.

Larson village population size is estimated to have been between 430 and 560 people.

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CHAPTER I

DEMOGRAPHY OF NORTH AMERICAN INDIAN SKELETAL COLLECTIONS

I. INTRODUCTION

The demographic parameters of past populations only recently have been explored in depth by a small minority of researchers in physical anthropology. Progress in this area results from the application of statistical procedures used on contemporary populations and by the development of accurate techniques for determination of skeletal age and sex. It long has been recognized that skeletons in archaeological context reflect the demographic characteristics of the populations they represent. However, the difficulties of examination and interpretation account for the sparsity and restricted scope of most past research.

As anthropologists seek to describe and explain the events occurring in past societies, it is essential to explore all avenues of study. Our investigations would be quite incomplete if we ignored the demographic aspects of past populations, especially now that a methodological and theoretical foundation has been established from which to proceed. The information gained about the demographic structure of an earlier population, its mortality rates, fertility and sex ratio, indicates how well that population was adapted to its cultural and physical environment. Knowledge of these factors helps explain why a particular population existed as it did, why it grew in size or declined towards extinction, even why certain cultural practices may have

developed and continued. "Accurate evaluations of population size, density, and structure have become increasingly essential to the interpretation of population-environmental relations and to the attempt to reach an understanding of prehistoric cultural process" (Ubelaker 1974:1). Aboriginal demography allows us to examine the developmental trends in human life spans and mortality (Acsádi and Nemeskéri 1970). And, ultimately, a more complete understanding of the past is essential to our knowledge of the future: "it is likely that a good knowledge of the past will yield new insights into the underlying causes of population change that . . . will stimulate further research on the current population trends" (Hollingsworth 1969:25). Above all, the anthropologist concerned with earlier populations cannot avoid entanglement with demographic issues. Wobst (1973:vii) demonstrates this point by acknowledging that even the most

> trite archaeological data are structured at least in part by demographic factors and their derivatives. Thus, the age and sex structure of a population will be reflected, if only indirectly, in the number of points, the volume of pots or the size of houses encountered by archaeologists. More complex archaeological parameters are more intricately structured demographically. For example, the mean length of occupation of residential structures not only derives from the mating pattern, the postmarital residence rules and various other social and economic factors, but also from mortality (household abandonment) and fertility (rate of new household formation).

Essentially, demography is the statistical study of populations. The search for demographic variables and the role they play in extinct human cultural systems is called either paleodemography (Angel 1969a; Acsádi and Nemeskéri 1970) or prehistoric demography (Howells 1960; Cook 1972). Reconstruction aims of paleodemographic studies are divisible into two aspects: (1) the determination of total population size and (2) the calculation of vital statistics. Following Angel's

(1969a:427) lead, vital statistics may be summarized as including the reconstruction of the

> age composition of the population, mortality at different periods of life, adult longevity of each sex, sex ratios of adults and children, fecundity and if possible, fertility, birth and death and natural increase rate, family size . . . and if possible the critical effects of nutrition, disease, and physical exertion.

Examination of the literature indicates that numerous approaches deriving from all branches of anthropology, especially archaeology, are applicable to the detection of demographic characteristics of past populations. The physical anthropologist, using data obtained from examination of human skeletal material, is an important information source. For instance, demographic analysis of the age and sex distribution at death of a skeletal series provides insight into population mortality, longevity, sex ratios, disease, trauma, and cultural stress (Lovejoy 1971). Due to the nature of the material studied by the physical anthropologist, it has been suggested that the quality of information obtained is superior to that achieved by archaeological methods.

> It is evident that the more use is made of factors having a biological component, the closer one comes to the reality of population, a biological phenomenon. Finally, we come to skeletal material, the most important evidence of all, since it is completely biological, and one individual however many rooms he may occupy or however many clams he may eat or pots he may make, produces one skeleton and one only (Howells 1960:160).

II. PALEODEMOGRAPHIC STUDIES OF AMERINDIAN POPULATIONS BASED ON OSTEOLOGICAL ANALYSIS

Paleodemographic studies in the New World unfortunately are quite rare. Few skeletal series from archaeological sites are available

which adequately satisfy the necessary preconditions for demographic analysis, the primary problem generally being inadequate sample size. Ubelaker (1974:64) recently encountered this deficiency: "Of all skeletal samples previously reported for Aboriginal North American Indian populations, only the Huron ossuary described by Anderson (1964) offers a sample suitable for meaningful demographic comparison [with the Nanjemoy skeletal collection]." The few investigations available, however, do provide valuable information concerning mortality and population numbers in indigenous groups. Previous research also establishes the methodological procedure for future studies. Definitely the present research derives from its antecedents. For this reason I briefly survey past literature pertaining to osteologically based demographic research in Amerindian populations.

The foundation for any demographic research utilizing skeletal collections in physical anthropology began with Todd (1920-1921) and Todd and Lyon (1924-1925). Todd established several standards for skeletal age changes allowing more accurate assessment of age at death. Since Todd's early work, other ageing criteria have become available, and techniques were refined. One difficulty now encountered is the fact that earlier demographic analyses were limited to available, but less reliable, criteria. Interpopulation comparisons require caution if different means of age estimation were employed. Population differences in mortality may be real or a result of systematic biases inherent in the ageing methodologies.

Hooton's (1920) analysis of the cemetery sample from Madisonville, Ohio, marks the beginning of New World demographic research. The primary objective was to estimate the mean death rate and total number of

occupants in the nearby Indian village. To determine the death rate, Hooten argued that a close relationship exists between the mean annual death rate and the age distribution at death. The Madisonville age distribution, as ascertained from the skeletal series, was compared with age distribution of death in several European countries of known crude death rate. Census data of Switzerland most resembled the Madisonville population; the latter was consequently assigned Switzerland's crude death rate, though Hooton did modify this death rate believing it slightly higher. Once the population crude mortality rate was known, this value, together with the number of years of cemetery use and the total number of graves, allowed determination of the village population size.

Hooton's (1930) later report on the Pecos Pueblo gained even more recognition. This demographic analysis attempted to reconstruct the growth and decline of the Pecos population during the approximate 1000 years of occupation. Hooton calculated the total number of individuals who lived at Pecos and the number present during each of the stratigraphic periods. According to archaeological progress maps, approximately 15 to 20 percent of the cemetery site was excavated (Hooton 1930:334) and yielded approximately 1800 burials. Hooton assumed that the rest of the site would yield a directly proportionate amount, a total of 9000 to 12,000 burials. Discrepancy arose when historic documentation of the later periods of pueblo occupancy indicated this total to be far below the expected. A population between 1000 and 1500 individuals (as indicated by historical evidence) with a crude death rate of 25-30 per 1000 individuals per year should have produced 22,500 to 45,000 burials. In all, the total number of deaths

was estimated to have been 50,000. From this value the number of occupants during each archaeological period was ascertained. To do so he assumed that the number of known burials from each period directly reflects the proportion of the total 50,000 in residence at Pecos. Unfortunately, accuracy of the conclusions is severely limited by the large number of uncontrolled variables. Hooton's early demographic endeavors, however, gave impetus for later demographic investigations.

Snow (1948) and Johnston and Snow (1961) aged and sexed the Indian Knoll Archaic collection and determined its mortality curve. Demography of the Indian Knoll population indicated a high infant mortality rate, and the greatest number of adult deaths occurred between 25 and 34 years of age. Although this population is large and potentially very informative, the results are not strictly comparable with mortality curves of other populations due to the ageing criteria. The initial report by Snow aged adults by cranial suture closure, a criteria now known to be unreliable (Singer 1953; McKern and Stewart 1957). Johnston and Snow (1961) reanalyzed much of the collection to remedy the situation. A composite of ageing criteria was utilized for the reassessment, though Stewart (1962) has emphasized that even more reliable ageing techniques are available.

Goldstein (1953) reported on skeletal material dating 800 to 1700 A.D. recovered from different geographical regions in Texas. Observations of vital statistics were comprehensive and included sex ratio of the population, sex differences in mortality, and age-specific mortality. Goldstein then used these demographic statistics to test the relationship between subsistence level and mortality. Comparison was made between the average length of life attained in agricultural

versus hunting-and-gathering populations. Although results were inconclusive, the report paves the way for additional problem-oriented paleodemographic research concerning causes of trends in the history of human life spans.

Paleodemographic analysis of ossuary deposits initially was attempted by Churcher and Kenyon (1960) on two Iroquois ossuaries. Unfortunately the Tabor Hill ossuaries partially were destroyed by looters and bulldozing equipment prior to formal excavation. In total, 213 individuals were actually recovered, though this figure was modified to 523 to account for destroyed and missing burials. Population mortality and the sex ratio were examined. Sex ratio for the skeletal population was highly skewed, young males being deficient. Churcher and Kenyon considered this to reflect a large loss of males during warfare, with their bodies not being returned for burial. Regional population size contributing to the ossuaries was then estimated using the mean annual death rate (determined as described by Hooton 1920), the time interval of the ossuary deposits (inferred from historical records), and the estimated number of burials in the ossuaries. Major ageing criteria again emphasized the use of cranial suture closure.

The most comprehensive demographic investigation of ossuary skeletal samples is by Ubelaker (1974). The investigation concerns the Juhle site, two prehistoric Late Woodland ossuaries in southern Maryland. Unique to New World investigations, this report applies life tables to the description of population mortality. Demographic data provided includes population longevity, mortality, life expectancy at each age, and age-specific probabilities of death. Life tables

permitted calculation of the population crude mortality rate. Population size contributing to each ossuary was calculated by the life table crude mortality rate, the total number of individuals buried, and the time interval represented by the ossuary deposits. Of major importance is the attention given to selection of the ageing criteria. The commingled nature of ossuary skeletal material generally prohibits identification of all bones of each individual. This prevents simultaneous consideration of several ageing criteria, with independent assessments being made for several bones. For instance, in the case of adults the investigator establishes curves of death either by observation of morphological changes in the pubic portion of the innominates or by internal bone remodeling of the femur (osteon counts). Ubelaker applied both approaches,comparing their results in order to determine the best approximation of the population's mortality profile. Mortality for the population indicated that the highest frequency of death occurred during the first five years of life. Maximum frequency of adult death occurred at 30 to 35 years.

Mortality profiles were calculated for a Middle Mississippian population of 479 individuals from Dickson Mound, Fulton County, Illinois, by Blakely and Walker (1968). As is common, highest frequency of death occurred at birth. Sex differences in mortality indicated a lower average age at death for females by approximately four years. Relative to males, female mortality increased at 18 years and remained higher until age 30, a difference possibly associated with childbirth difficulties. Average age of death for the population (sexes combined) was about 23 years.

Blakely (1971) later compared mortality profiles ascertained from four prehistoric Amerindian skeletal collections. Average age at death for an Illinois Archaic population was 27 years, for Middle Woodland Hopewell 30, and for a Middle Mississippian group 24. To determine the cause of apparent differences in mortality, Blakely (1971:43) emphasizes that "the investigator must take into account such forces as subsistence patterns, disease vectors, conflict behavior, and funerary practices." Average age of the Hopewell series, for example, is believed to reflect funerary practices, with many subadults presumably buried elsewhere. Again, the data reveal differential mortality by sex. Mean age of death for males was greater than for females. A higher frequency of female than male deaths occurred during the third decade.

Buikstra (1972) utilized burials from two Middle Woodland mound groups--Pete Klunk and Gibson--in the lower Illinois River Valley, to estimate minimum population size of the associated Gardens of Kampsville habitation site. The investigation also considered the amount of labor available for subsistence activity in a community of this size. To determine the age distribution, Buikstra used one of the functions of the population's life table.

The final demographic study is most relevant to the present research as it concerns a population from the Middle Missouri Valley. The skeletal series from the Leavenworth site (39CO9) cemetery was demographically analyzed by Bass, Evans, and Jantz (1971). The village associated with the cemetery dates from approximately A.D. 1803 to A.D. 1832. Mortality profile of the population indicates a high infant mortality (nearly 40 percent) with only 5.6 percent of the

people surviving past 40 years of age. In all, a high mortality rate was experienced by the Leavenworth people due to warfare, disease, and increasing European encroachment. Unfortunately, one difficulty encountered is that burials recovered do not accurately reflect the total number of deaths in the village. Comparison of population size as estimated by burial count and historical sources indicates a sample deficiency. Apparently an additional cemetery(s) was present.

III. DEMOGRAPHIC ANALYSIS OF THE LARSON POPULATION

The reconstruction of demographic data--mortality rates and population size--is crucial to our understanding of aboriginal populations. Certainly the previous investigations briefly summarized demonstrate this potentiality. Unfortunately, this past listing of osteologically based demographic researches also indicates a noticeable deficiency in number. Skeletal samples of the New World frequently are limited in size or have failed to meet necessary assumptions for demographic analysis.

This research has the benefits of an unusually large skeletal collection (sample size equals 706) from the Larson site (39WW2), Walworth County, South Dakota. In addition, complementary information from archaeological and historical sources allows control of variables often not present in other demographic investigations. This skeletal series provides an excellent opportunity for demographic analysis and can be used to explore unique problems concerning demographic reconstruction. The Larson site represents a time period of increasing European influence on Arikara populations, especially with reference to communicable diseases. It also has been hypothesized that the

village was abandoned due to an epidemic. The site will aid our understanding of populations in the Middle Missouri River Valley during the eighteenth century.

Major objectives of this study are to reconstruct vital statistics of the Larson population and to determine population size of the nearby village which contributed to the cemetery. Outline of the topics for discussion is as follows: In Chapter II, excavation history and pertinent archaeological data essential for demographic analysis are reviewed. Hypotheses important for the interpretation of the Larson mortality profiles are presented. Chapter III considers the preconditions of demographic analysis in order to determine Larson's fulfillment of these criteria. The methodology (ageing and sexing standards and the demographic approach) utilized for examination of the skeletal series is discussed. Chapter IV inspects vital statistics of the Larson population by presenting data on mortality, survivorship, age-specific probability of death, life expectancy, and crude mortality rates. Interpopulation comparisons are made to determine differences unique to the Larson mortality profile. Causes of death are examined using available historical information and results from paleopathological analysis. Demographic data are applied to test the epidemic hypothesis. Validity of the life table approach is then appraised by examining the error introduced in life table values by brief but serious fluctuations in population mortality experiences. In conclusion, population size of the village is estimated by use of the crude mortality rate, the number of years represented by the skeletal deposits (determined from archaeological and historical data), and the total number of individuals recovered from the cemetery.

CHAPTER II

THE LARSON SITE

I. EXCAVATION HISTORY AND ARCHAEOLOGICAL DATA

The Larson site (39WW2) is located on the east bank of the Missouri River approximately two miles south and east of Mobridge, Walworth County, South Dakota. The general location in the Missouri Valley is within the Grand Moreau region about five miles south of the juncture of the Grand River with the Missouri. Figure 1 shows the exact location of this site. The site is comprised of a protohistoric fortified earth-lodge village and its associated cemetery. Larson village occupied what was formerly a high terrace overlooking the Missouri Valley; the cemetery area ascends a slope approximately 100 to 300 yards east and north of the village. Figure 2 shows the dispersion of burial pits within the cemetery; only the burial pit number is given, although one pit often contained several individuals.

Village excavations were initially conducted by River Basin Survey crews under the direction of Dr. Alfred Bowers in the summers of 1963 and 1964. Twenty-nine circular depressions were visible within a stockade and ditch fortification system. Of these, time allowed complete excavation of three lodges and test trenching of an additional ten (Smithsonian Institution n.d.a). On the lodge floors numerous human skeletons were found, much of this skeletal material being scattered and disarticulated. "We have discovered that more than 50 percent of the lodges so tested have human skeletons spread out over the floors . . ." (Bowers n.d.b). The lodges had collapsed

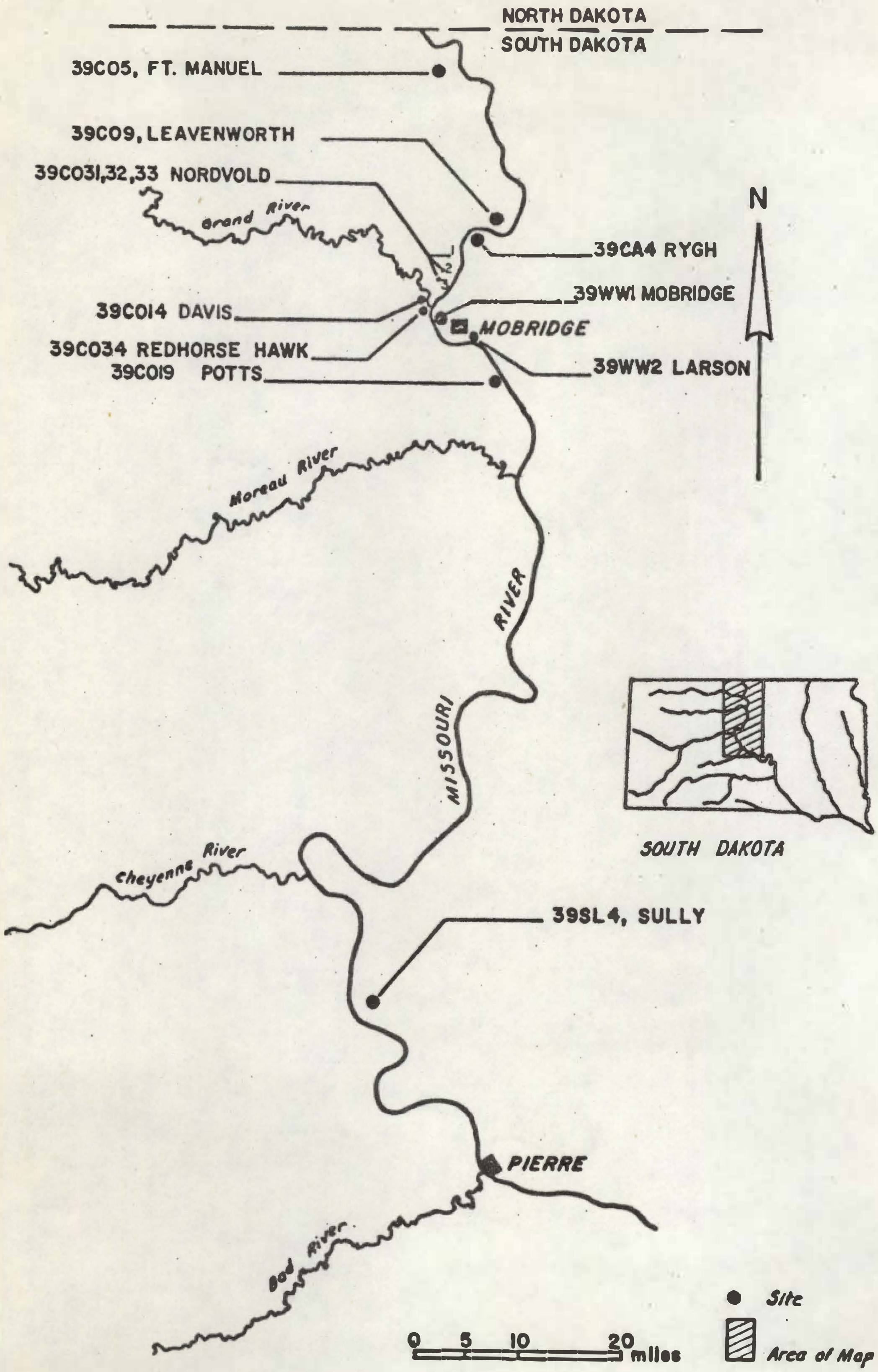

Figure 1. Location of the Larson site (39WW2).

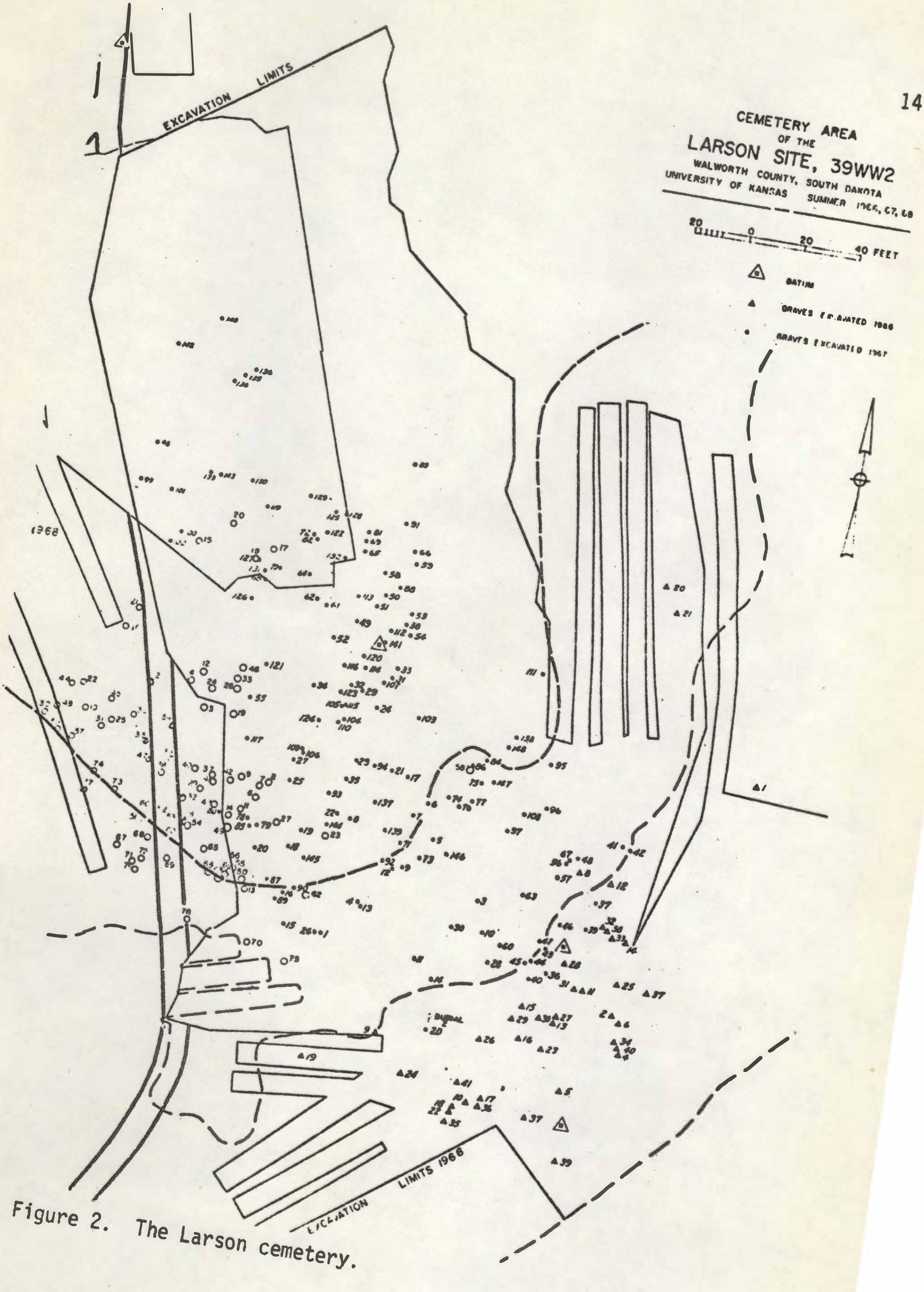

Figure 2. The Larson cemetery.

due to burning and thus covered the skeletons, although evidence suggested that the lodges were standing for some time (possibly a year or two) after deposition of the bodies (Bowers n.d.a, n.d.b, n.d.c). Bowers (1967:205) later summarized his conclusions about Larson as follows:

> Excavations at the Larson site (39WW2) revealed an early Woodland horizon largely destroyed by the later occupation of the site during protohistoric times. Unlike most earthlodge sites, it was situated away from the river channel and the population relied on a large spring nearby for their water. The site was strongly fortified with a ditch and remnants of an older ditch could be traced. It had been burned several times. Burials were found in three lodges but cache pit burials were also common. The site seems to be the end of a local tradition long in existence near the Grand River.

Further excavation at the Larson village was conducted in 1966 by J. J. Hoffman of the River Basin Surveys, Smithsonian Institution. "A test trench 5 feet in width and 150 feet in length was projected into the village area from the northern periphery. Two fortification ditches, several caches, at least three houses, and other structural features were revealed" (Smithsonian Institution n.d.b). As in previous excavations, some human skeletal material was recovered.

Beginning excavation of the nearby cemetery was also initiated in the latter half of the 1966 field season by University of Kansas crews under the direction of Dr. William M. Bass. A thorough and complete salvage excavation of the burial area was conducted during this and the following two field seasons (1966, 1967, 1968). All possible means, including the use of heavy earth-moving equipment, were utilized to recover and preserve all skeletal material in the cemetery area. Fortunately there was complete excavation of the cemetery site and partial excavation of the village as the Larson site is now entirely

inundated by waters of the Oahe Reservoir. In total, 706 individuals were recovered from the village and adjacent cemetery area, the largest skeletal collection available from one site in the Northern Plains. Obviously, this is an excellent opportunity for demographic analysis.

II. TRIBAL IDENTIFICATION OF THE LE BEAU PHASE AND LARSON SITE

Lehmer and Caldwell (1966) and Lehmer (1971) introduce the culture classificatory system of the Middle Missouri Valley followed in this analysis. Major taxonomic units for this hierarchical classification are the tradition, variant, and phase. A tradition is subdivided into finer units--the variants:

> It is possible . . . to assign the great majority of the known village components to a variant of one of the cultural traditions. These assignments have been made on the basis of geographic distribution, age, and such traits as settlement pattern, fortification systems, basic house type, certain pottery characteristics, and the presence or absence of some diagnostic artifact types (Lehmer 1971:33).

Within each variant, subcategories--the phases--may be recognized. The subsequent discussion concerns the cultural taxonomic and tribal identity of the Larson village. The above-listed sources form the basis for much of the following.

Within the Middle Missouri Valley two cultural traditions of Plains villages occur--the Middle Missouri tradition and the Coalescent tradition. These cultural traditions are each crosscut by variants--Initial, Extended, and Terminal Middle Missouri; and Initial, Extended, Post-Contact, and Disorganized Coalescent. The Larson site belongs to the Coalescent tradition, and more specifically the Post-Contact variant of the Coalescent tradition. European influences, increasing

intertribal commodity exchange, increasing warfare, and introduction of the horse are all factors which helped shape and differentiate the cultural configuration of the Post-Contact Coalescent villages from the earlier Coalescent variants.

Five phases have been isolated for the Post-Contact variant--Talking Crow, Felicia, Bad River, Heart River, and Le Beau. The Larson site is classified as one of the type sites representative of the Le Beau phase (Lehmer 1971). Ethnohistoric documentation indicates that three village tribes were present in the Middle Missouri Valley at the time of Larson's occupation--the Arikara, Mandan, and Hidatsa. The culture of the historic Arikara was an outgrowth of the earlier Extended Coalescent variant. Mandan and Hidatsa roots are in the Middle Missouri tradition (Lehmer 1971:136). Tribal identification of the Le Beau phase and the Larson site are generally accepted as being Arikara, though it has been suggested that Le Beau is Mandan. For example, Bowers (1950:116-117) writes that "According to tradition, this group [Awigaxa Mandan] lived near the Grand River until late prehistoric times. . . . ." Elsewhere Bowers (1965:484) notes that the Mandan lived in this locality until after A.D. 1700. Archaeological data does not support this possibility. "The absence of Middle Missouri tradition sites near the Grand River and the geographic extension of Le Beau phase sites as far south as the lower Bad-Cheyenne region argue against the identification of the Le Beau as Mandan" (Lehmer 1971:203). Additionally, Larson burial customs include primary interment, flexed burial type, and wood covering of burials--traits which correspond with burial practices at other Arikara cemeteries (Bass n.d.a).

Larson's ethnic identity can also be clarified by examination of the biological data--skeletal morphology. By application of multivariate analysis, specifically Mahalanobis' generalized distance, canonical variate analysis, and cluster analysis, Lin (1973) demonstrated the morphological dissimilarity of Mandan and Arikara crania. The results of this research suggest that Larson is most appropriately classified as Arikara. Jantz (1973) evaluated the taxonomic identity of Larson by means of a two-group discriminant function, Arikara versus Mandan. This function classified Larson as an Arikara population. As both biological and archaeological data concurrently distinguish Larson as an Arikara settlement, this interpretation is more probable.

III. DATES OF THE POST-CONTACT VARIANT AND LARSON SITE

The Post-Contact variant is an outgroth of the earlier Extended Coalescent variant. Although similar manifestations, Lehmer (1971) notes that differences, especially in village pattern and pottery, do occur. The major factor of distinction is the arrival of European trade materials into the valley; A.D. 1675 is the approximate date of this beginning influx. Accordingly, this is the earliest date for the Post-Contact variant of the Coalescent tradition. Larson is definitely temporally associated with this protohistoric period as evidenced by a large quantity of European trade goods (Jantz 1970).

Beginning occupation of the Larson village occurred about or slightly before A.D. 1750 (Jantz 1970; Lyon 1970). This initial date was suggested because of the similarity in village pattern, especially the presence of a fortification system and closely spaced earth lodges,

with dated villages of other Post-Contact Coalescent phases. Specifically, the Bad River phase of the Bad-Cheyenne region exhibits a subphase with a similar pattern dating after 1740 (Lehmer and Jones 1968).

Village abandonment is probably a result of the introduction of epidemic diseases into the Middle Missouri Valley during the years 1780-81. Historical documentation records the appearance of highly contagious diseases and gives many indications of the devastation and high mortality rates experienced by native populations. Termination of the Post-Contact variant of the Coalescent tradition is attributed to cultural disruption caused by the smallpox pandemic of this time period (Lehmer 1971). Lehmer and Jones (1968:91-92) wrote "that the epidemic of 1780-81 precipitated a major sociocultural deterioration among the Arikara. This is evidenced in part by a sharp reduction in the number of occupied villages, and by a high degree of geographic mobility during the closing years of the eighteenth century."

In summary, relative chronology dates the Larson site to approximately A.D. 1750-81. As length of residence is a major consideration in demographic analysis, a different aspect of the time factor is discussed in following chapters.

IV. TERMINATION OF THE LARSON OCCUPATION BY DISEASE--A HYPOTHESIS

Epidemic disease, especially smallpox, is hypothesized to be the major cause for Larson's abandonment. During village excavation, numerous scattered and disarticulated human skeletons were located on the earth lodge floors, which is a highly unusual burial pattern in the

Plains. Bowers (n.d.b) reported: "At first it was thought that the village had been attacked, its occupants slaughtered, and the lodges burnt. However, this position is no longer defendable in light of the scattering of the bones and we now hold to the position of an epidemic in which the bodies were left in the lodges to be scattered by animals." Archaeological evidence also suggested "that at first there was an attempt at covering the bodies in the center of the lodge around the fireplace, and that the last ones were left lying about on the floor" (Bowers n.d.d). The cemetery excavations presented concurrent conclusions. As excavation progressively moved farther up the hill, the more traditional Arikara burial patterns seemed apparent. Bass and Ubelaker (n.d.) believe the lower burials, those closest to the village, were probably smallpox victims.

Bass (n.d.a) applied three different lines of research to test this hypothesis: (1) Comparison of the Larson burial pattern with other protohistoric Arikara cemeteries; (2) radiographic analysis of skeletal material to determine the presence of osteomyelitis variolosa, pathological bone changes which may result from smallpox infection; and (3) isolation of smallpox virus antigens in soil and skeletal samples from Larson by agar gel diffusion tests and protein determination. Examination of the burial patterns demonstrated that, in general, Arikara cemeteries exhibit consistency in burial practices. Larson, however, does have a higher frequency of multiple interments, and burial in earth lodges is unique. Furthermore, some skeletal material does evince symptoms possibly related to smallpox, though results of the biochemical analysis proved negative. Failure to detect smallpox antigens precludes definite association of the disease with the Larson

site, although other characteristics are easily explainable by an epidemic. Bass (n.d.a:68) summarized possible events that occurred in the Larson village as follows:

> During the summer an epidemic struck. The first to succumb were the infants and the aged. These earliest deaths were buried in the cemetery following the cultural pattern for burial, but probably in haste, as suggested by the occurrence of many multiple interments and some burials placed above the wood covering. Later, the adolescents and the few young adults began to become ill and the remaining population possibly panicked, leaving the village to the adolescents and a few adults, sick or dead and not buried.

Demographic analysis of the Larson skeletal collection is an additional means of testing this epidemic hypothesis.

CHAPTER III

PRECONDITIONS FOR PALEODEMOGRAPHIC ANALYSIS AND METHODOLOGICAL PROCEDURES APPLIED

I. OVERVIEW

Complete demographic analysis of skeletal remains has rarely been undertaken in the New World because samples fail to satisfy prerequisites for analysis. Briefly summarized, these preconditions are: (1) a knowledge of sample completeness, (2) ability to accurately assess age and sex of the skeletal collection, (3) knowledge of the length of time represented by a skeletal sample, (4) information concerning archaeological associations of the series, and (5) application of appropriate demographic methodology (Acsádi and Nemeskéri 1970; Ubelaker 1974; Vallois 1960). If these requirements are satisfied, demographic analysis provides much new information about the population. If certain factors are questionable, this alters accuracy of the results and must be considered.

In this chapter, the preconditions for demographic analysis are examined in depth to determine how well the Larson skeletal collection satisfies them. The methodological procedures utilized are also discussed.

II. COMPLETENESS OF THE LARSON SKELETAL COLLECTION

Sample inadequacy has been a major deterrent to demographic studies. It is important to determine if a skeletal collection

constitutes an unbiased sample of the living population. Three sources of bias are particularly important and may result in an inadequate representation of the population's parameters: (1) partial destruction of the series, (2) exclusion of population members from burial in the cemetery area for social or cultural reasons, and (3) failure of the anthropologist to collect and save all skeletal material for subsequent analysis.

Partial Destruction of the Skeletal Series

Skeletal samples may be partially destroyed through several means, notably construction activities, looters, and differential preservation of skeletal remains.

Of major concern to analysis of Larson is loss of skeletons due to construction activity. The impetus motivating the Missouri Basin salvage program was construction of the immense Oahe reservoir system, thus causing inundation of numerous archaeological sites. The salvage program surveyed and sampled as many sites as possible prior to their disappearance. The Larson site excavations were given the attention of several seasons of excavation. Initial investigations in the village area by Bowers recovered human skeletal remains in all three of the excavated earth lodges. Also, "there is evidence of additional skeletons in the remaining lodges" (Smithsonian Institution n.d.a:14). Hoffman (n.d.b) later uncovered more human skeletal material. Less than half of the lodges within the village fortification system were sampled, and additional lodges were present outside the fortification ditches. The probability is high that more skeletal material is present in the unexcavated area. This does indicate some sample

incompleteness concerning the total number of skeletons present in the village. Skeletal material recovered from the village represents the aberrant Arikara burial pattern which has led to the suggestion that smallpox was the cause of village abandonment. The recovered sample from this area tabulates to 78 individuals which should allow interpretation, with caution, of the reason responsible for these findings. An incomplete sample is still useful for determination of vital statistics if the collection adequately represents the mortality profile of the original group.

Excavation of the associated cemetery began in the latter half of the 1966 field season because the rising water level was eroding skeletons out of the bank. Each year this problem continued as the water level gradually rose up the slope of the burial areas. Excavation records indicate that at times workers were only one step ahead of the water line. Undoubtedly there was some loss of skeletal material because of this, though the actual number missing is believed to be minimal. Bass (1975) believes that at least 90 percent of all skeletons in the cemetery area were recovered. The loss should not greatly alter conclusions derived in this report concerning vital statistics of the Larson population. A total sample of 706 should adequately represent the population. Determination of the total number of residents occupying the village does require some correction to account for lost skeletal material. Otherwise, population size will be underestimated.

Loss of skeletal material resulting from other causes as looting or differential bone preservation is minimal. In general, bone preservation is excellent, and differential preservation is not

a source of bias. Numerous reports (Acsádi and Nemeskéri 1970; Angel 1969a; Goldstein 1953; Stewart 1969; Vallois 1960) mention loss due to lack of preservation of less durable osseous material. This usually results in systematic loss of juvenile skeletons (primarily infants), and females or pathological specimens may also be selected against.

Exclusion of Population Members Due to Social or Cultural Reasons

A cemetery may not be representative of the entire number of deaths occurring in a population due to exclusion of specific individuals for social or cultural reasons. For instance, in some groups social customs dictate that certain members, e.g. newborn infants, receive different mortuary treatment; or members of military expeditions may be lost in battle and not interred within the designated burial area. Post-Contact Coalescent village tribes characteristically practiced primary inhumation with graves typically grouped in a cemetery located near the village (Lehmer 1971). The Larson skeletal series probably represents the majority of individuals who occupied the village. There are no apparent indications of exclusion of population members due to social or cultural reasons with one possible exception--the skeletal material recovered from the earth lodges and village area.

One other consideration concerns the possible existence of an undetected additional cemetery for the Larson population. Estimation of population size from the number of skeletons in the Leavenworth cemetery (39CO9), another Arikara village in South Dakota, indicated the presence of at least one additional cemetery (Bass, Evans, and Jantz 1971:161). Whether or not Larson exhibits a similar situation is unknown; there are no surface indications of auxiliary cemetery

areas (Bass 1975). Further light may be shed on this question and the possibility of other socio-cultural preburial selective patterns after examination of available skeletal material. My initial assumption is that the people buried their dead in the known cemetery during the entire period of village occupation, and that the recovered skeletal series is an unbiased representation of the population.

contrast w/ Hurt's seasonality

Collection of All Skeletal Material

The application of demographic methodology to the analysis of skeletal material from archaeological sites requires that all bone recovered be saved for analysis. Earlier excavation techniques often deemphasized the need for complete salvage and failed to collect and preserve all skeletal material. Bone in relatively poor condition, skeletons which lacked certain crucial parts (notably the skull), or juvenile skeletons were not retained for later study. The bias of the collector produced a sample with overrepresentation of favored types of specimens in the collections (Stewart 1969). Demographic analysis of skeletal material obtained by inadequate sampling theory introduces systematic error. Fortunately, present excavation methodology emphasizes the collection and preservation of all skeletal material.

> If population studies are to be conducted, great care should be taken to determine (1) where the burials came from (village or cemetery area), (2) how much of the burial area was excavated, and (3) what was brought back, i.e., were infant skeletons, subadults or broken material discarded in the field. This information must be known before studies on death rate, population distribution and population change can be meaningful (Bass 1969:461).

In this regard, the Larson skeletal collection represents an excellent opportunity for demographic analysis since not only every skeleton, but every bone was saved.

III. DETERMINATION OF SEX AND AGE

Demographic analysis of an archaeological population requires correct determination of age and sex of the individual skeletons. Accuracy of any interpretations concerning population vital statistics is dependent upon the criteria selected for ageing and sexing the skeletons. Methods available do produce dependable results, although there are certain problems. The following discussion notes these problems, and then consideration is given to methods utilized in analysis of the Larson skeletal series.

Problems in the Determination of Sex

Examination of the sex ratios obtained in a large series of skeletal populations indicates that there has been a systematic bias in sexing of adult skeletons. According to Weiss (1972, 1973), adult sex ratios should generally approximate a 1:1 ratio; yet published data favors males by approximately 12 percent. Possible reasons suggested by Weiss for the unbalanced sex ratio are (1) the tendency to consider unknown specimens as males, and (2) the possibility that cultural practices, as differential burial practices, are present. To avoid errors in sexing adults from the Larson site, analysis was preceded by an initial determination of criteria which are reliable indicators of sexual dimorphism within this population. These sexing procedures were then applied to the entire collection, followed by rechecking much of the material. Additionally, much of the adult skeleton material has been studied previously in craniometric analyses which required determination of sex. Thus, opinions of other observers were available.

The second major hindrance to determination of sex from skeletal material has been the lack of accurate criteria applicable to subadults. Differential sex mortality could not be ascertained from juvenile skeletons prior to the approximate age of 15.

Methods for Sex Determination of Subadults

Prepubertal sex differences allowing sex determination with confidence would be of great aid to the paleodemographer. Studies of sex differences in infants and fetuses demonstrate that sexual dimorphism is present even at this early age. Boucher (1955, 1957) observed significant differences between male and female fetuses in the subpubic angle of the pelvis and in the width and depth of the sciatic notch. Measurements taken on roentgenograms of the pelvic girdle of infants (during the first postnatal year) also showed significant differences (Reynolds 1945). However, the application of results and methods from these studies to sex determination of infants is difficult when only skeletal material remains. Many of the dimensions which show sexual variation are impossible to measure from the skeleton alone without associated soft tissues. Examination of the sciatic notch appears to be the most promising as a possible method for sex determination of infant skeletons. Yet, Boucher (1957) cautions that more research is necessary to determine applicability of this method in all populations. Sex differences in the fetal sciatic notch are statistically significant in American Negro and British white populations but are not in American white infants. Likewise, sex differences in innominate bones of children have been reported (Reynolds 1947; Imrie and Wyburn 1958). By roentgenographic examination of the bony pelvis in early childhood, Reynolds discovered sex

differences in measurements, angles, and indices; although again these conclusions are not directly applicable to skeletal research. A method for sexing designed specifically for specimens of unknown sex and age was tested by Bailit and Hunt (1964). The mandibular teeth were rated as to their developmental stage by both male and female ageing standards. Sex was assigned on the presumption that the ageing standard for the correct sex should produce less variability in developmental ages of the separate teeth. Regrettably, only limited success was achieved; the correct sex was chosen in 58 percent of the test cases.

Hunt and Gleiser (1955) have developed a more reliable method for sex determination of subadult skeletal material. This technique is based on the observation that sex differences in dental maturation are less pronounced than in skeletal development. "If bone and dental ages are assessed for the remains by the standards of both sexes, the sex for which the standards agree best is considered to be the correct one" (Hunt and Gleiser 1955:486). Tests of this method on living children show improving accuracy with increasing age. Results are relatively good--73 percent of the two-year-olds were correctly sexed, 76 percent at five years, and 81 percent at eight years of age. Bone biological age is estimated by comparison of the hand skeleton to radiographic standards. One prohibitive problem in applying this technique to archaeological specimens is that the small bones needed are easily lost or destroyed. Hunt and Gleiser (1955) suggest that the knee region may serve the same purpose, although this has not been tested for accuracy. For this reason, another method of sexing subadults was employed.

Determination of Sex of Larson Subadults: Dental Discriminant Sexing

Recent developments in the sexing of skeletal remains based on tooth size differences demonstrate that accurate diagnosis may be achieved. Univariate consideration of dental measurements has shown that there are significant size differences between the dentitions of males and females (Garn, Lewis, and Kerewsky 1964, 1966). Even though the mean for a particular tooth measurement is distinctive for the sexes, the range of overlap prohibits reliable sex determination based upon this single observation. Simultaneous consideration of several dental measurements by the application of multivariate statistics overcomes this problem and allows diagnosis with the reliability required. The relevance of discriminant function analysis using dental measurements to the problem of sex diagnosis has clearly been demonstrated by Ditch and Rose (1972). The accuracy achieved in correct sex classification by the various discriminate formulae presented by Ditch and Rose ranges from 88.4 percent to 95.5 percent. Breitburg (n.d.) recently developed dental discriminant formulas for a different archaeological skeletal sample. Results again substantiate the dependability of dental discriminate formulas for skeletal sexing.

This new technique was designed purposely by Ditch and Rose to aid in sex assessment of poorly preserved skeletal material. In addition to this application, it is possible to apply multivariate analysis to the problem of sex determination of immature skeletons. Measurements required for the development of discriminant formulas are obtained from the permanent dentition; of these the anterior teeth were shown by the previous studies to be most valuable as a contributor

to sex diagnosis. Alveolar eruption of the teeth needed for measurement begins at approximately six years of age and is generally completed by twelve. If variable measurements are obtainable from the erupted permanent dentition, estimation of sex may be achieved by a discriminant function. A sufficient number of teeth have erupted in Larson subadults by approximately nine years of age. The minimum age sexed by a discriminant formula was found to be seven. This was extremely rare, only twice--a result of mandibular damage causing the unerupted teeth to be separated from the mandible and thus measurable.

The assessment of the sex of immature skeletons by multivariate discriminatory analysis may be attempted in two ways: (1) collecting dental measurements of the unknowns and then using the discriminant formulas developed in previous studies (i.e. Ditch and Rose 1972; Breitburg n.d.), or (2) developing discriminant formulas designed specifically for the Larson population. The first possibility (No. 1 above) assumes that interpopulation sexual variation is similar, thus allowing discriminant formulae based upon one population to be applicable to another. Difficulties inherent in this assumption have been noted before (Birkby 1966). Therefore, to justify following this procedure requires testing the accuracy of the available discriminates on a sample of Larson adults which are sexable by other means. To develop discriminant functions for the Larson population also requires measurement of the dentition of sexed adults and the subsequent calculation of the discriminant formulas. This second alternative was selected. Both procedures would have required examination of adults. More importantly, the power of discrimination

of a formula is likely to be greater when used on the population for which it was designed.

To develop the discriminant formulas used in this study, the dentition of adults which were sexable by the innominates was measured. Generally only young adults (below the approximate age of 35) were measurable as dental attrition rendered older individuals inadequate. In addition, skeletons lacking more than one dental measurement were eliminated. The resultant base population with complete or very near complete sets of dental measurements consisted of 17 males and 21 females. In the few cases of missing data, the mean for that variable as derived from the whole sample was substituted. According to Howells (1973) this procedure does reduce the variance-covariance matrix of the dental measurements. Fortunately, necessity required doing so infrequently and should have little effect on decreasing variance and correlation.

Although this series is small, the discriminant functions derived for this base sample should be applicable to other samples from the same population. Any deleterious effects due to sample size are a minimal handicap relative to possible errors resulting from use of discriminants based on other populations. At the very least, use of Lårson discriminants eliminates error due to differences in measurement technique between various observers.

Four dental discriminant functions were calculated using procedures of the Biomedical series (BMD04M), a two-group discriminant function program (Dixon 1967). Each formula weights the variables to maximize correct sex classification. Table 1 gives the formulas, variables, and sectioning points (male discriminant scores being larger

TABLE 1

DISCRIMINANT FORMULAS DEVELOPED FOR THE LARSON POPULATION

	Formula	Percent Correct Classification of Base Sample	Division Point
A.	Z = c(0.04576) + h(0.08726) + i(0.06277)	89.5	1.47221
B.	Z = e(0.19908) - g(0.19615) + h(0.15814) + i(0.20515) - j(0.14152)	92.1	0.98907
C.	Z = - a(0.04940) + b(0.03148) + c(0.07499) + d(0.00642) + e(0.02456) + h(0.10884) + i(0.04066)	89.5	1.81970
D.	Z = - a(0.11851) - b(0.01051) + c(0.05714) - d(0.00086) + e(0.29949) - f(0.01097) - g(0.25600) + h(0.23403) + i(0.20081) - j(0.16457)	92.1	1.02880

Variables:

<u>Maxillary</u>

a. B-L Incisor 1
b. B-L Canine
c. M-D Canine
d. B-L Premolar 1

<u>Mandibular</u>

e. B-L Incisor 1
f. M-D Incisor 1
g. B-L Incisor 2
h. B-L Canine
i. M-D Canine
j. B-L Molar 1

than the listed division point). The percent correct classification of the base sample is also recorded and indicates 90 percent accurate classification of the known base sample.

Variables used in the discriminant formulas emphasize the anterior dentition and especially bucco-lingual tooth dimensions. In total, 22 maxillary and mandibular measurements were actually taken on the base sample. From these 22, 10 variables were selected for use in the discriminant formulae. Selection was based on the following considerations:

1. Tooth contact facets at the mesial and distal borders appeared to increase in depth with advancing age modifying this dental dimension and adding age-related variation. Partially for this reason, mesio-distal measurements were avoided.
2. Garn, Lewis, and Kerewsky (1966) observed greater sexual dimorphism in bucco-lingual tooth diameter than for mesio-distal diameter in Ohio whites.
3. Previous dental discriminants for skeletal populations demonstrate the importance of the anterior dentition by computing the discriminant rank order of the variables (Breitburg n.d.). Garn, Lewis, and Kerewsky (1966) discovered a similar relationship in Ohio whites.
4. Teeth exhibiting pronounced sex differences in mean value for a measurement were included.

Dental measurements were taken with calipers equipped with a vernier scale allowing readings of 0.1 mm. Bucco-lingual and mesio-diameter measurements are defined according to techniques of Ditch and Rose (1972:62), as follow:

1. Mesio-Distal (M-D) Diameter--Taken along the plane bisecting the occlusal surface of each tooth with end points located at the wear contact facets. Rotated teeth were measured where contact facets normally occur. Canines and incisors were measured at the mesial and distal crests of curvature.
2. Bucco-Lingual (B-L) Diameter--Taken perpendicularly to the plane of the occlusal surface, end points located at the crown midpoint. Incisor and canine measurements were taken on the root just below the cemento-enamel junction.

Measurement techniques are illustrated in Figure 3.

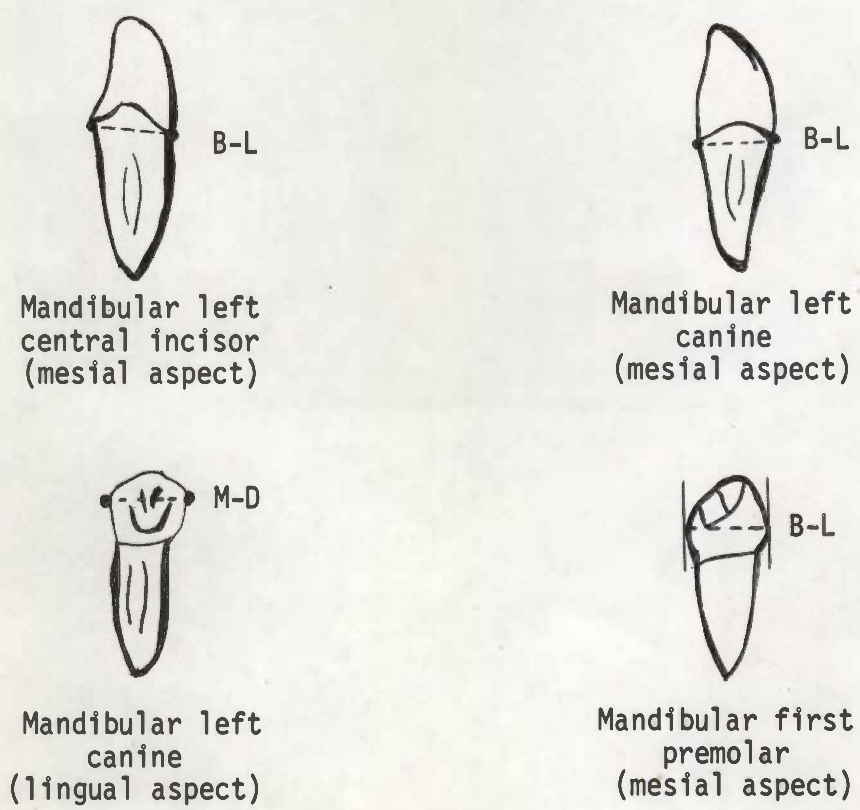

Figure 3. Dental measurements used for discriminant formulas.

<u>Sexing of Adult Skeletal Remains</u>

As sexual dimorphism is much more apparent in adult skeletal morphology, sexing is less problematic than sexing of immature specimens. Much research has concerned sexing of adults, and numerous criteria and techniques are now available. For analysis of the Larson skeletons, several of these criteria were considered in order to achieve reliable diagnosis.

In general, pelvic morphology has proven to be most reliable as an indicator of sex (Bass 1971; Krogman 1962; Phenice 1969; Washburn 1948). Phenice (1969) discusses three characteristics of the pubic portion and ischiopubic ramus of the innominate bone which allow correct sex determination in approximately 95 percent of the cases. Visual observations utilized in this method which are typical of females are the ventral arc, a subpubic concavity, and a narrow medial aspect of the ischiopubic ramus. Other morphological traits which vary in relation to sex include the subpubic angle, width of the sciatic notch, presence of a preauricular sulcus, and rugosity of the sacroiliac articulation (Bass 1971; Krogman 1962). The presence of scars of parturition, a by-product of the childbirth process (Stewart 1957, 1970), are also diagnostic.

Cranial morphology is also useful for sex determination as several criteria are available which serve to distinguish the sexes (Bass 1971; Krogman 1962; Stewart 1968). Morphological sex traits of the skull found to be beneficial for the analysis of the Larson collection include general size and ruggedness, the degree of muscle marking present in the occipital region, variation in size of the supraorbital

ridges, rounded or sharp margins of the upper orbital border, and shape of the chin.

Discriminant function analysis of anthropometric measurements of the adult cranium is an additional procedure aiding sex determination (Giles and Elliot 1963; Giles 1964, 1970). These prior studies indicate that an approximate accuracy of 82-89 percent is attainable. This approach was not utilized directly by the author, as Lyon (1970) conducted research involving discriminant function sexing of the Larson population. Results of this previous analysis with regard to sex determinations were available for consideration by this investigator.

Sex differences occurring in long bones were utilized for this analysis. Consideration was given to visual observations as the presence of septal apertures or measurements (as diameter of the femoral head), as these criteria may aid in identification (Bass 1971; Krogman 1962; Pearson 1917-1919). In all, numerous factors were considered in order to achieve accurate sex determination of the Larson skeletons.

Problems in the Determination of Skeletal Age

Age determination provides the core information required for demographic analysis of a skeletal population. In general, the use of five-year age intervals is recommended, as smaller categories exceed the ranges of confidence of available ageing techniques and thus may be misleading (Swedlund and Wade 1972). The major difficulty encountered in ageing a skeletal population concerns older individuals. Traditional ageing criteria become insufficient for ageing within the suggested age categories for adults older than approximately 45 years. Weiss (1973) notes that in much of the published data concerning skeletal populations,

maximum age of death is 45 to 50 years. The assertion is that available ageing methods tend to systematically underage adults as the fertility required to maintain these populations would be too high. Weiss (1973) suggests that the investigator select a preconceived maximum expected age of about 75 years in order to avoid bias resulting from underageing. The oldest specimen of a skeletal population is assigned this upper category with subsequent ageing relative to this fixed point. Another possible method of avoiding age underestimation of individuals older than 40 years is to increase width of the final age interval. Bennett (1973) tested the effect of lengthening the terminal age category on the life expectancy at birth as ascertained from a life table. By successively increasing the final age category by 10-year increments from 40-50 years to 40-90 years, he demonstrated that "the actual width of the interval has relatively little effect on the average expectation of life at birth since deaths are not evenly distributed at the extremes of the life span" (Bennett 1973:225).

For analysis of the Larson collection, it was decided to consider the maximum age category to be 55-59 years. The ageing criteria available to the author do not allow dependable age determination beyond this interval. The failure to raise the upper age category to the interval suggested by Weiss (1973) may have resulted in some bias; however, conclusions derived from data of which I am uncertain would equally introduce error. Undoubtedly some members of the Larson population did attain ages greater than 60; historical documentation of the Arikara records such evidence:

> I observed some very old men amongst them. . . . One day, in passing through the village, I saw something brought out of a lodge in a buffaloe robe, and exposed to the sun; on

> approaching, I discovered it to be a human being, but so shrivelled up, that it had nearly lost the human physiognomy. . . . On inquiring of the chief, he told me that he had seen it ever since he was a boy. He appeared to be at least forty-five. It is almost impossible to ascertain the age of an Indian when he is above sixty, I made inquires of several, who appeared to me little short of a hundred but could form no satisfactory conjecture (Brackenridge 1904:122-123).

The actual number of individuals possibly underaged by delimiting the upper age category is a minority of the population. Results derived should not drastically be altered by this missing information.

Determination of Subadult Age

Two methods were used to estimate chronological age of immature skeletons from the Larson population--dental calcification and longitudinal bone growth.

Of all the developmental phenomena which allow estimation of chronological age, the dentition provides the most reliable information. Correlation studies of tooth formation and eruption as compared with osseous maturation have demonstrated that a relationship does exist between maturation of these tissue systems (Demisch and Wartman 1956; Lauterstein 1961). The variability of tooth formation as compared with chronological age does increase with age; however, this variability is of less magnitude than for osseous development (Garn, Lewis, and Polacheck 1959; Lauterstein 1961; Lewis and Garn 1960). A high genetic component is responsible for dental development. Garn, Lewis, and Kerewsky (1965) suggest that the variation in dental maturation of a sample is largely due to genetic differences, with only 10 percent of the variation being the result of nutritional differences. The dentition is also less subject to developmental advancement or retardation than are the bones in cases of endocrine

imbalance, disease, or major physical defect (Garn, Lewis, and Blizzard 1965; Niswander and Sujaku 1965). In other words, these considerations emphasize that examination of dental development will produce the most accurate estimation of chronological age. Dental development was the major criteria for age assessment of the Larson subadults.

Dental age may be estimated by examination of either of two features--dental eruption or dental calcification. Dental eruption has been extensively utilized by earlier studies, the most frequent standard for analysis being a dental eruption chart compiled by Schour and Massler (1941, 1944). Tooth eruption was not used in this analysis due to the possibility of overageing when using the Schour and Massler standard (Merchant 1973; Ubelaker 1974), a tendency probably resulting from the limited sample from which the dental chart is constructed (Garn, Lewis, and Polacheck 1959). One other limitation of tooth eruption as a means for ageing is the deviation in eruption time which may follow premature loss of deciduous teeth (Fanning 1962). Fanning's research demonstrated that tooth formation is less affected by this type of environmental insult.

The dental calcification standards used for ageing are from Moorrees,Fanning, and Hunt (1963a, 1963b). These studies provide the age norms and standard deviations for the formation of ten permanent teeth (two maxillary and all eight mandibular) and formation and root resorption for three deciduous teeth. Chronological age of an unknown is estimated by first rating each tooth according to its developmental stage. Ages for these degrees of crown or root development are provided by the standards; specimen age is then assigned the

average age indicated by the teeth considered. To allow examination of the developing teeth, periapical dental X-rays of the Larson subadults were taken whenever necessary.

Although the Moorrees, Fanning, and Hunt dental charts provide separate sex information, it was necessary to pool their data to allow age determination when sex was unknown. Unavoidable bias in age ascertainment results from this practice as the sexes do differ slightly in chronology of dental maturation (Garn and others 1958; Hunt and Gleiser 1955; Moorrees, Fanning, and Hunt 1963b). According to Garn and others (1958) this divergence is least early in life and increases to a maximum of 5 percent; in general, females are approximately 3 percent ahead of males in the time of dental maturation.

The application of these dental standards to groups other than the population for which the charts were designed is a second factor introducing possible error. "Thus, in another population, the children may pass through these stages of dental development in the same sequences . . . but consistently earlier or later" (Moorrees, Fanning, and Hunt 1963b:1500). Available information on the dental eruption time schedule in American Indian populations indicates that some differences are present. Comparison of normative data of whites and Indians suggests that advancement in time of dental eruption occurs (Garn and Moorrees 1951; Hrdlička 1908; Steggerda and Hill 1942). Dahlberg and Menegaz-Bock (1958) note that Pima Indian children are relatively advanced in eruption of posterior teeth, but exhibit later eruption of the anterior teeth. Yet, before major compensation is possible by adjustment of the ageing criteria, several difficulties must be resolved. Ubelaker (1974:45) summarizes this problem:

> Unfortunately the studies do not agree on the actual eruption ages for various teeth, and it is not clear from the discussion whether the variance is due to population genetic variation, dietary-nutritional differences, or methodological discrepancies.

Even if variation does occur in dental eruption, differences in dental calcification still remain unknown. Merchant (1973) suggests that if any tooth is advanced in maturation relative to whites, it is the second permanent molar. She advises avoiding this tooth for ageing purposes when possible. For the present analysis, this practice was followed. No other attempt was made to compensate for racial differences in dental calcification.

Age estimation based on skeletal development is achieved by measurement of diaphyseal length of the long bones and comparison of these values to growth standards correlating bone length with chronological age. The two major reference studies presenting information on bone length associated with age which have been utilized by past researchers are Johnston (1962) and Stewart (1968). Johnston examined bone growth occurring up to 5.5 years of life in subadults from the Indian Knoll site, an Archaic population. Stewart (1968) compared length of Eskimo femora with chronological age (as estimated by dental eruption) in order to develop regression lines expressing this correlation and allowing unknown specimens to be aged.

Recently the results of a third cross-sectional growth study based on skeletal material became available. This study (Merchant 1973) is most appropriate for the present analysis as the population examined is protohistoric Arikara from the Mobridge site, Walworth County, South Dakota. Data presented includes means and standard deviations of bone length attained per chronological age for the

following: diaphyses of the six long bones, breadth of the ilium, and six different measurements of the mandible. Chronological age was estimated by two separate techniques: (1) the Schour and Massler (1941, 1944) tooth eruption chart and (2) the dental calcification standards of Moorrees, Fanning, and Hunt (1963a, 1963b). As the dental standards of the latter were utilized for analysis of Larson subadults only, the Merchant charts recording bone growth per chronological age as determined by dental calcification were applicable. These standards should allow determination of subadult age, which is relatively comparable to ages obtained by dental formation.

Determination of Adult Age

Adult ages of the Larson population were determined by observation and consideration of numerous criteria. Final judgment, however, was derived by weighting the emphasis placed on these criteria according to demonstrated dependability.

The metamorphosis of the pubic symphysis was the single most important factor considered for age determination. For Larson males aged 17 to 40, the McKern and Stewart (1957) system was applied. This method recognizes three components of the pubis--the dorsal plateau, ventral plateau, and symphyseal rim, which undergo age-dependent morphological changes. One handicap to this system is the limited effectiveness beyond the age of 40 years; any specimen of greater age is classified only as being 40 plus. To resolve this difficulty, any individual rated by McKern and Stewart system as being older than 40 years was additionally aged by standards derived by Todd (1920-21). Todd established ten phases, based upon consideration of nine

characteristics of the symphyseal region, which document metamorphosis of the pubic symphysis and allow age estimation from 18-19 years to 50 plus years. This extension of the age range was particularly useful as it permits age determination of males older than the capabilities of the more recent McKern and Stewart system. Accuracy decreases, however, as the Todd system may tend to overage (Brooks 1955). In order to apply this system, Todd's illustrations and descriptions were used to age skeletons older than 40 (as predetermined by the McKern and Stewart [1957] system). Individuals were classified within 10-year intervals, either 40-50 or 50-60 years. To allow examination of the mortality profile by the standard 5-year intervals, the author simply halved the number in each 10-year category. This procedure assumes equal mortality for the adult ages of 40-45 compared with 45-50, and 50-55 compared with 55-60. This probably is not the case, yet is unavoidable due to inability of the Todd system to age within the narrow gradations required.

Females of the Larson site were aged by the Gilbert and McKern (1973) system, a standard derived specifically for females. Prior to this, it was necessary to use the McKern and Stewart (1957) system for females. Possible error due to the lack of comparability prompted Stewart (1957) to caution that mortality curves which demonstrate sex differences in a population are questionable. Gilbert and McKern (1973:39) support this contention noting that "the regular metamorphic changes observed in the female os pubis are different from those seen in the males both in rate of maturation and locality." Use of this system avoids a possible systematic bias of earlier demographic studies. Additionally, the Gilbert and McKern standard allows age

determination of individuals older than 40 years. The same procedure of ageing within 10-year intervals and then halving this number was necessary, however, as the female standard is not capable of classification within 5-year categories at these upper ages.

Degree of epiphyseal closure was considered to be an important ageing criteria for young adults. The age distribution for stages of union were derived from the standards of young American males presented by McKern and Stewart (1957) and McKern (1970). The following is a partial list of epiphyses examined for degree of fusion: epiphyses of the long bones, epiphyses of the iliac crest and the ischium, the medial clavicular epiphysis, and epiphyseal rings of the vertebral bodies.

Other ageing criteria of much less reliability, which were used only for general age ascertainment, are: (1) development of vertebral osteoarthritis, (2) cranial suture closure, (3) dental attrition, and (4) ossification of rib cartilage. Stewart (1958) examined the degree of osteophytic lipping associated with chronological age; results indicated that this feature is of some value for age identification. The amount of closure of endocranial and ectocranial skull sutures was examined using standards presented by Krogman (1962) and McKern and Stewart (1957). Because of the unreliability of this method for individual age determination (Singer 1953), little emphasis was given this technique. One exception was the basilar suture which has been shown to be reliable as an age indicator (McKern and Stewart 1957; McKern 1970). Standards relating general age categories with stages of dental attrition provided rough age estimation (Brothwell 1965; Hrdlička 1952). Likewise, ossification

of rib cartilages at the costrochondral junction allowed general age ascertainment (Kerley 1970).

To summarize, subadult age was determined by dental calcification. Osseous development provided supplemental information. Morphological changes of the pubic symphysis and epiphyseal closure are the important criteria for adult age determination. Other criteria were of minor importance. In general, a complete or near-complete skeleton was available for examination. The only major exception was skeletal material recovered from one of the earth lodges. A total of 44 highly scattered and disarticulated skeletons were present. Commingling prevented association of all bones with each individual. Age and sex determination was achieved by examination of the pelvis. Merchant (1973) standards of innominate growth allowed subadult ageing. Adult ages were by pubic symphysis standards. The rest of the skeletal collection was not so limited, the author having entire skeletons for ageing and sexing purposes.

IV. TIME INTERVAL REPRESENTED BY THE SKELETAL SERIES

Knowledge of the time period represented by the skeletal sample is vital for reconstruction of village population size. Previous discussion (see Chapter II) proposes an approximate interval of 31 years (A.D. 1750-1781) for the length of village occupation. Unfortunately more precise dating is unavailable, although this estimate is reasonable and agrees with historical evidence of Arikara village movement patterns. According to Holder (1970), duration of village

occupancy was related to the amount of arable land and wood supplies obtainable from the river bottoms. "As these resources were depleted the location of the village shifted, following a slow cycle of some fifteen to thirty years" (Holder 1970:35). Archaeological data provides additional evidence supporting the proposed occupation time span.

Village midden accumulations of 5 and 6 feet in depth were reported by Bowers (n.d.a, n.d.c). Excavation of the lodges indicated rebuilding several times (Bowers n.d.e, n.d.f); Lodge 1, for instance, was rebuilt twice. Ethnographic information concerning Hidatsa earth lodges, structures similar to Arikara lodges in both materials and construction, record that lodges ordinarily last from seven to ten years (Wilson 1934:372). Presumably Arikara lodges were comparable in such statistics. Building and rebuilding of Lodge 1 and the Larson village could have occurred over a 30-year interval.

At this point one other question needs consideration: Was the Larson village occupied year-round during the 30 years of residence? Traditionally the Arikara were characterized by a shifting settlement pattern. "The occupation of these villages was only nominally permanent. Throughout the year the village might be virtually abandoned for considerable periods of time" (Holder 1970:35). Will and Hyde (1917:58) reported that the Arikara abandoned their permanent villages for three to four months during winter and moved to more sheltered areas with abundant fuel supplies in the river bottoms. Basically similar earth lodges were constructed in these winter encampments. Lengthy hunting expeditions also caused near-total village abandonment (Abel 1939:74).

Hurt (1969) has synthesized the archaeological data and historic information concerning Arikara economic activities and associated seasonal settlement patterns. This source is the basis for much of the following discussion pertaining to Arikara yearly settlement activities.

During the spring (March-May) the people were settled in the agricultural villages for purposes of planting the neighboring fields. In June and July villages were abandoned for the summer hunt. The majority of village inhabitants moved onto the prairies and lived in tipis while hunting buffalo. Only the old, sick, and incapacitated remained in the village to guard the fields. Tabeau (Abel 1939:74) mentioned the occupants of a village he visited in 1804, the major body of village inhabitants having left:

> On my arrival at their village, I found there only some old people exposed to every danger and hardly keeping up the remnant of their vitality with flowers of the summer pear, with young branches of willow, with sweet grass, and other herbage. Even after the return of the hunters, who for two months scoured the prairies, and until the young pumpkins were eatable, the three villages lived in a state of destitution which would pass among us for dreadful famine.

August and October was the harvest season; hunters returned to the agricultural settlements to the crops. In November and December, many villagers again left the villages for buffalo hunting. Finally, with coming of the coldest weather (January-February), the Arikara villages were completely abandoned. A move was made to winter settlements located in the bottom lands. Sheltered areas provided protection against inclement weather, and firewood was abundant.

Changes during the postcontact period essentially caused abandonment of these traditional settlement patterns. Decimation by disease and warfare with the Dakota Sioux forced villagers to

occupy settlements year-round. Will and Hyde (1917:110) write "that the Hidatsas and Arikaras went on extended summer hunts in early days; but by the year 1815, weakened by smallpox and hemmed in by the Sioux, they were compelled to give up these tribal hunts as a regular practice." The practice of abandoning villages during winter persisted a little longer. Movement of hostile war parties was impeded during winter (Will and Hyde 1917). Apparently villages were still being abandoned in 1826; the Arikara are described as "having leather lodges, which they use in the winter season, when they leave their dirt villages to occupy some convenient point for fuel and pasturage . . . " (U.S. Secretary of War 1826).

Apparently the traditional seasonal shifting in settlement patterns was still followed during Larson's occupation. A terminal date of 1781 predates disruption of these activities. People were not occupying the Larson village throughout the entire year. The recovered burials represent only certain seasons. From the model presented, the total population was in residence for planting (March-May) and harvesting (August-October), or a total of six months during each year. Larson was abandoned during winter (two months) presumably by the total population and at least by a majority during the months of extended hunting expeditions (November-December and June-July). Only the old and disabled remained in the village. So actually the time factor for village occupation is not 31 years, but less. If we compensate by deducting two months from each year to allow only for winter abandonment, the length of occupation is 25.8 years. If the village was vacant an average of four months per annum, the time is 20.7 years. The extreme limit of village abandonment is six months

per year. In this case villagers were consistently absent during winter and the four months of hunting expeditions. If the village was unoccupied for half of each year for 31 years, the time factor for village residence is 15.5 years.

The evidence presented definitely indicates the need for some correction of the proposed time span of village occupation. To assume the population was in residence for a total of 31 years would underestimate the total number of village inhabitants. Alternatively, the other extreme (15.5 years) is not reasonable. People (although fewer in number) probably were in residence at Larson during the periods of extended hunting trips. A moderate estimate of village abandonment for an average of four months during each year is more justifiable. This estimate takes into consideration the winter move and partially compensates for population size decrease due to buffalo hunting. Examination of the population sizes estimated by these different time spans should validate these proposed modifications concerning the Larson length of residence.

V. ARCHAEOLOGICAL ASSOCIATIONS OF THE SKELETAL SERIES

Archaeological associations of a skeletal series provides information necessary for interpretation of a population's mortality profile. Origin of the sample, burial chronology, and inferences about socio-economic differences are possible contributions of demographic significance. In the case of Larson, evidence of a possible epidemic (as indicated by archaeological data) is an excellent example. At this point, much of the archaeological data relevant to the present investigation has previously been mentioned. One final consideration

involving examination of two forms of archaeologically based information (burial spatial location and the burial associations) remains as it will allow more complete demographic analysis of the Larson population.

The entire skeletal series is the collective result of approximately 30 years and thus reflects the mortality experiences throughout this period. If, for the moment, we assume that the village people did suffer an epidemic, some of these burials probably relate to this occurrence. The majority of burials presumably represents normal pre-epidemic mortality experiences of the populace. Ideally, if epidemic victims were identifiable and separable from the "normal" segment of the sample, information concerning two different demographic events (the normal underlying mortality and disease-related mortality) could be extracted. Actually, some evidence does suggest that a distinction is possible and thereby justifies additional attention. Obviously, skeletons recovered from the village, the aberrant burial pattern, are readily suspect for epidemic-induced mortality. Likewise, an area of multiple inhumations in pits lowest on the cemetery hill supports this hypothesis (Bass n.d.b; Bass and Ubelaker n.d.).

One criterion which may aid identification and separation of victims of the suspected epidemic is time. Skeletons recovered from the village lodges definitely date to the terminal occupation period of Larson (Bowers n.d.g). Any burials in the cemetery which are due to the same cause of death must likewise be relatively recent. Burial chronology needs to be established in order to identify the earliest and, more importantly, the latest burials of the village occupants.

The initial step for establishing burial chronology was division of the cemetery into smaller units. Four subareas were

identified (designated areas I, II, III, IV) to allow intracemetery comparison of the frequency of specific grave artifacts associated with burials of each subarea. Figure 4 shows the divisions of the cemetery. Partitioning attempted to delineate natural clusters of burials identifiable on the excavation maps, although at times boundaries were arbitrarily imposed. Area I is lowest on the cemetery slope; this division roughly corresponds with the area mentioned by Bass (n.d.b) and Bass and Ubelaker (n.d.) as possessing distinctive features. Areas II and IV are located higher up the hill; Area III is highest and includes burials spatially located most distant from the village. The village outer perimeter is visible in the lower left corner.

Examination of the archaeological associations of the burials allows determination of the relative chronology of the cemetery subareas. Frequency of particular burial artifacts--the presence of European trade goods--was determined for each division. Presumably a higher frequency of European products and materials associated with the burials identifies subareas most recent in time; that is, if burial location was determined by calendrical date and if the frequency of European trade goods increased in abundance during the 30 years of village occupation. Alternatively, an equal distribution of European objects might be obtained in the different subareas, a case if burials were rather randomly placed throughout the cemetery during its period of use.

Trade materials first entered the Missouri Valley as early as A.D. 1675, a result of the fur trade industry (Lehmer 1971), which led to the development of a highly complex intertribal commodity exchange system. The Arikara were ideally located for positions as middlemen

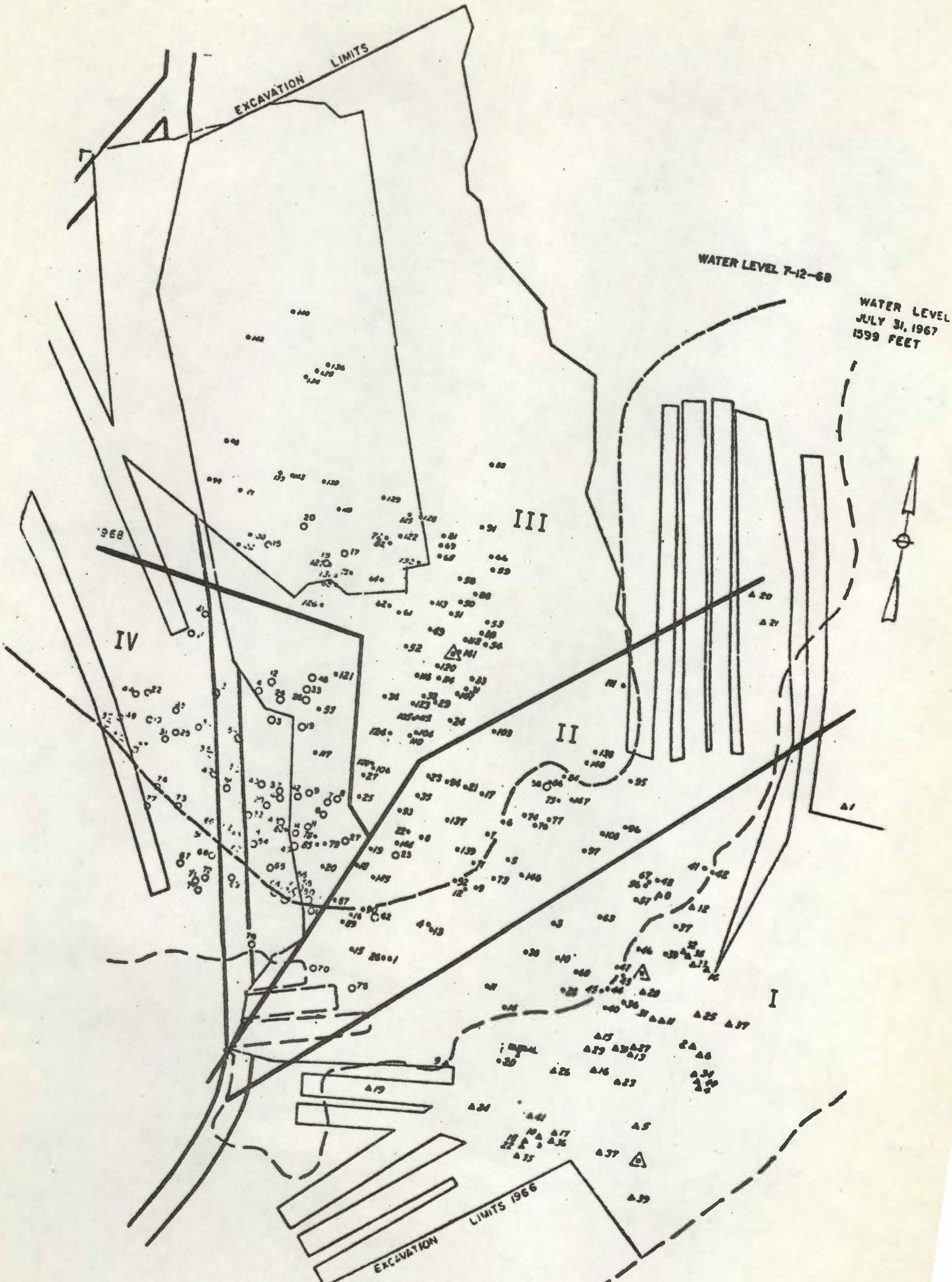

Figure 4. Subareas of the Larson cemetery.

and "brokers" for this trading network and consequently realized considerable profit (Lehmer and Jones 1968). During the years of Larson's occupation, this intertribal trading system was fully operative. European products increased in abundance, and this increase is probably reflected in the quantity of this type of grave association.

To test this possibility, the presence or absence of European elements (i.e. metals such as brass, iron, and copper, or glass) was recorded for each burial. Mr. Marc Rucker (n.d.) has analyzed the Larson burial artifacts and kindly made available the data necessary. Complementary information was also supplied by the Larson field excavation records (Bass n.d.c). Table 2 lists the number of burials with European trade goods for each area, the total number of burials in each area for which such was recordable (salvage conditions due to the rising Oahe waters prohibited data collection in some instances), and the percentage of burials with European artifacts.

TABLE 2

PERCENTAGE OF EUROPEAN ARTIFACTS ASSOCIATED WITH BURIALS OF DIFFERENT CEMETERY LOCATIONS

Area	Number of Burials with European Artifacts	Total Number of Recorded Observations	Percent
I	9	138	6.5
II	8	133	6.0
III	37	131	28.2
IV	34	149	22.8

The lowest areas of the cemetery hill (Areas I and II) record the smallest percentage of burials with European artifacts affiliated, an average of 6.3 percent. Frequency of trade goods with burials from Area IV has markedly increased; and Area III, the division farthest up the cemetery slope,has the highest frequency, 28.2 percent. Apparently the Arikara initially buried in the lower regions of the cemetery and gradually ascended upward. Initial burial was in Areas I and II; then Area IV, a space fairly close to the village; and then, during the last years of village occupation, the dead were carried to Area III for burial.

An alternative explanation for this phenomenon is differential mortuary practices according to societal status. People of high status would have had greater access to European commodities. Likewise these same individuals were possibly accorded burial in select locations, Areas III and IV for instance. From the data presented, either explanation is reasonable and would account for observed differences in frequency of European burial accompaniments. Information presented in the following chapter attempts to resolve this dilemma by examination of the sex ratio and age distributions of these different spatial locations. The objective is to isolate victims of the smallpox epidemic which is believed to have occurred.

VI. PALEODEMOGRAPHIC METHODOLOGY

Selection of appropriate demographic technique was the final requisite for analyzing the Larson skeletal collection. At present, three techniques have been utilized for estimating vital statistics from skeletal remains of extinct populations. These methods are discussed

with their assumptions and limitations, in order to assess the applicability of each to the Larson population.

Determination of Demographic Parameters with United Nations Model Life Tables

Bennett (1973), in his investigation of the Point of Pines, Arizona, skeletal collection, used United Nations model life tables. Such model tables were designed to help determine demographic parameters of underdeveloped countries where data are often inadequate. The pattern of high birth and death rates in undeveloped countries and historical populations suggests that these models and the methods are applicable to prehistoric populations (Hollingsworth 1969). Bennett matched the model U.N. "stable population with the observed population, thereby estimating the demographic characteristics of the latter by attributing to it the characteristics of the former" (Bennett 1973:228). The assumptions are: (1) that the observed population was stable, and (2) "that the demographic parameters of the actual population approximate one of a family of model stable populations" (Bennett 1973:228).

A stable population has constant mortality and fertility rates and a constant rate of natural increase (Hollingsworth 1969). Bennett's procedure, which allows for the possibility of natural increase, differs from both the conventional approach used in life-table construction, which is based on an observed schedule of age-specific death rates, and from the strategy which requires a stationary population (i.e. a stable population with zero growth).

Carrier (1958) discussed whether or not the U.N. tables actually are a good source for the determination of parameters of ancient populations. He notes that these models are derived from

post-1920 populations, where mortality often has been influenced by programs for control of infectious disease and thus differ from prehistoric populations. Application of the procedure to the Point of Pines archaeological population was considered by Bennett (1973) to be only partially successful. The major limitation of the method is that a value called r (the intrinsic rate of increase for a population) must be known or very closely approximated. As shown by Carrier (1958) and later by Bennett (1973), this is a potential source of considerable error. Carrier (1958) did design a means of sidestepping the r requirement but cautioned against use of this alternative. As there is no estimation of the r value for the Larson population, this approach was not used in this analysis.

The Angel Approach to Demography

Angel (1947, 1955, 1958, 1968, 1969a, 1969b, 1971), using information extractable from both bones and graves, has estimated some demographic parameters for selected Mediterranean populations. Angel's technique utilizes both the age distribution of deaths and estimates on numbers of children each woman has produced ("realized fecundity"). Fecundity is determined from the changes in the pubic bones (parturition pits) which result from childbirth. From these data, the birth rate, average female fertility, family fertility, adult longevity, and population growth rate may be estimated. This method also permits determination of the population age composition without depending on life table assumptions.

The limitation of this approach lies in accurately estimating fecundity. For example, Gilbert (1973:37) states: "After examination

of some 140 cases of known parity, it does not presently seem possible to determine the number of pregnancies an individual has experienced simply by noting the degree of damage done to the *os pubis*." Stewart (1970) agrees and notes that bone remodeling occurs with increasing age, thus eliminating much of the evidence. This approach was not used due to this limitation.

Examination of Mortality by Life Tables

The third approach for estimating mortality is the use of a life table presuming a stationary population. Life tables may be applied to archaeological populations by assuming that the age distribution at death, as determined from the skeletal deposits, accurately reflects age-specific mortality rates of the population. From the age distribution at death (Dx), the life table technique permits calculation of the probability of dying (qx) between exact age x and exact age $x + n$; the percentage of deaths (dx) between exact age x and age $x + n$; the percentage of survivors (lx) from one age to the next; the number of years lived by survivors at each age (Lx); the total number of person-years lived at each age or above age x (Tx); and the average number of years remaining to persons from birth and at each age (ex). (For a discussion of the relationships between these values, see Barclay 1958:93-122 and 186-297; also, Acsádi and Nemeskéri 1970.)

The probability of death for individuals at each age interval (qx) is a valuable statistic for interpopulation comparisons and is an index allowing determination of the age intervals most subject to death and disease (Swedlund and Wade 1972:112). Life expectancy (ex) is useful for comparison of different populations (Acsádi and Nemeskéri 1970; Swedlund and Wade 1972). Furthermore, this life table technique

allows calculation of the crude death rate, a variable necessary for estimating total population size. This methodology was selected for demographic analysis of the Larson skeletal collection rather than the Angel (1971) or Bennett (1973) approaches. It is therefore appropriate to examine both assumptions and criticisms of this approach to assess applicability to Larson.

The life table describes the mortality experience of a single cohort throughout its existence and as such treats the cemetery series as though representing a single generation. This supposition, when applied to skeletal samples, often the collective expression of mortality over several generations, is based on the assumption that through time "the sample has not been undergoing significant differences in the probability of dying with respect to age, and can therefore be treated as a reflection of mortality patterns at a given time in the history of the population" (Swedlund and Wade 1972:111). To construct a life table, one must assume that the population closely approximated a stationary population model. Stationary populations have constant vital rates,and the relative number of persons at each age and total census count remain uniform through time, in other words, a population with equal birth and death rates, a growth rate equal to zero, and fixed age-specific mortality rates. Equivalent birth and death rates cause the population size to remain unchanged, hence stationary. This assumption of stationary conditions allows treating the skeletal collection as though a single cohort. With fixed mortality rates, mortality of each cohort is presumed to reflect all other cohorts.

The second requirement for preparing life tables is that the population be closed--no in-migration or out-migration (Acsádi and

Nemeskéri 1970:61). Since the life table follows mortality of an assumed cohort, immigration of adults into a population tends to increase values of life expectancy, whereas emigration decreases them. However, if migration is reciprocal (as with mate exchange between clan groups), stationary population conditions are not violated (Weiss 1973:10).

The concept of stationary populations with zero growth rates seems invalid in consideration of today's rapidly expanding populations. Yet, this is likely to approximate historical reality for most earlier groups. Certainly for most nonhuman populations, it is apparent that unrestricted population growth is disadvantageous to survival; most approximate zero-growth equilibrium (Weiss 1975:48). Animal population density is believed to be self-regulated by numerous adaptive mechanisms for prevention of unrestricted growth (Wynne-Edwards 1962). "These natural populations tend to preserve a continuing state of balance, usually fluctuating to some extent but essentially stable and regulated" (Wynne-Edwards 1971:100). Human populations also have mechanisms for limiting rates of increase (Deevey 1960). In the case of earlier populations, those prior to the recent industrial revolution, the high birth rate was counterbalanced by a high death rate, thus producing stationary populations (De Jong 1972). Ascádi and Nemeskéri (1970:45) strongly support the theory of stationary population for paleodemographic analysis:

> Its importance lies in the fact that, with the exception of certain periods and areas, the rate of growth of human population was very slow even between 1 A.D. and the middle of the 17th century. According to estimates, the number of world population grew during these sixteen centuries from about 210-250 millions to nearly 550 millions, so the annual rate of natural growth may have been only 0.05-0.1 per thousand. Assuming that the first man using implements had appeared about half a million years ago, the size of the primordial population

> must have changed very little and its rate of growth must have been extremely low. It is obvious that in such circumstances--for lack of other data--the stationary model population is a hypothesis that approximates the one-time historical reality fairly well.

Finally, Weiss (1973:10) notes that even if a population's growth rate was not equal to zero, results obtained from using the stationary population model are not grossly inaccurate.

Disapproval of the life table approach for demographic analysis of archaeological populations is best formulated by Angel (1969a). Angel believes the following assumptions of the method to be invalid:

> . . . that the cemetery represents a single generation cohort, that death rates are even at all ages after infancy and hence directly reflected in cemetery age frequencies, and that the population is virtually stable biologically and socially over the period of cemetery use (Angel 1969a:428).

The treating of the skeletal series as a single cohort is extremely difficult to avoid, despite Angel's first criticism. This principle forms the basis of all the skeletal-demographic methodologies previously mentioned, including Angel's (see Angel 1971:69). One encouraging factor is that the Larson skeletal collection was deposited during a short time interval. Only a very few generations are actually represented.

The most important criticism is whether population stability may be assumed. Populations do not remain unchanging in their demographic features for long periods of time (Cook 1972; Hollingsworth 1969). However, in the case of archaeological populations, it is arguable that stability was maintained. These generally concern people prior to European contact, an era during which rapid fluctuations in population demographic parameters were not characteristic. Only with cultural contact and the subsequent nutritional and medical advances,

also the introduction of new diseases, did mortality and fertility rates drastically change.

Larson, however, is postcontact. The time period has been called "the heyday of Village Indian culture on the Middle Missouri" (Wedel 1961:194). It was also a time of changing tribal distributions, of the expansion of Siouan groups in the area followed by predation upon the sedentary villages, of increased European interaction with villagers, and the appearance of new epidemic diseases. Numerous sources may have altered vital statistics of the village Indian populations. Yet, because the Larson skeletal series represents a short period of time, changes in vital rates are probably minor. Analysis of the skeletal collection should accurately reflect mortality experiences of the Larson people during the years A.D. 1750-1781.

There is only one possible major demographic event which would have rapidly altered vital rates--an epidemic. Infectious disease may modify age-specific mortality differentially for the age classes; it can also increase mortality for all ages (Armelagos and McArdle 1975). massacre?

If Larson's abandonment was caused by smallpox, calculation of demographic statistics by consideration of all skeletons reflects both the underlying normal pre-epidemic vital statistics and disturbance in mortality rates caused by the epidemic. This presents a problem:

> A population undergoing serious demographic fluctuations cannot automatically be expected to deposit skeletons representing underlying average death rates. On the other hand, a population which *is* in age distribution equilibrium *will* deposit skeletal remains from which the exact age-specific death rates can be obtained . . . (Weiss 1975:54).

Obviously Larson belongs to the former category and demands caution in the interpretation of the mortality.

The error introduced may actually be much less than anticipated. Weiss (1975) examined the effect of demographic disturbances on the determination of normal population mortality rates as extracted from skeletal remains. By means of computer simulation, a stable population was allowed to accumulate graves for a total of three decades. The mortality experience was then changed by subjecting the population to a variety of demographic events (including epidemic conditions for limited intervals--one or five years). Graves were thus collected which reflected both normal and the disturbance-induced age-specific mortality rates. The resulting change was then compared with the underlying stable pattern; results were most favorable:

> In all cases, even for five-year events, the grave register will allow reconstruction of death rates to within 5% of their actual underlying value. For one-year events, the reconstruction is always within 2%. Apparently the accumulation of graves from many disturbed years (there are only three decades of initial undisturbed graves included at the beginning) has self-compensating properties. The more skeletons accumulated from "normal" periods, of course, the less effect disturbances will have.
>
> . . . .
>
> From this projection it seems clear that given the uncertainties in sampling, ageing and sexing of skeletons, demographic reconstruction from burial series is *not* vitiated by the occurrence of sporadic demographic events or stochastic fluctuations. A large cemetery can indeed be used with confidence that the general death rates derived from it will represent the prevailing demography of the time of deposit (Weiss 1975:55).

The Larson cemetery collection appears to readily fit the conditions simulated above. The skeletal series is large, contains a majority of "normal" skeletal deposits, and presumably suffered one major demographic disturbance. Furthermore, if village abandonment was caused by an epidemic, the time span represented was certainly less than Weiss's minimum time of disturbance. The skeletal deposits should adequately

reflect age-specific death rates for the Larson population during its years in residence.

The likelihood of an epidemic in the Larson population presents some interesting possibilities for demographic research. If the normal underlying mortality pattern can be effectively isolated by removal of smallpox victims from the sample, vital statistics can be determined on the "normal" deposits and the total combined collection. Comparison of these statistics allows inferences about the degree of alteration introduced by brief but serious fluctuation in a population's mortality rates. An estimate of the error resulting from the inclusion of smallpox victims is possible. Essentially this examines the reliability of present paleodemographic methodology based on osteological material. In the case of Larson, ethnohistoric sources mention disease as being one possible disturbance upsetting normal population processes. In prehistoric populations, however, information of demographic instability is unavailable and the paleodemographer proceeds without warning. Larson allows assessment of the error in demographic data caused by this lack of warning.

One final consideration concerning the stationary population model remains--the concept of closed population. As mentioned previously, an essential element for preparation of life tables is that the study population must not have experienced large amounts of in-migration or out-migration. In archaeological cases, this is an extremely difficult variable to control. Evidence relevant to Larson comes from inquiry into the nature of Arikara settlements.

Arikara villages of the postcontact period are characterized as being politically autonomous, endogamous communities comprised of consanguineally related matrilocal extended households (Krause 1972).

> Each riverine horticultural village was a territorially distinct unit of people sharing a common body of speech, tradition, and custom. This group had its own social hierarchy and its own methods of controlling labor, wealth and prestige. It normally acted as a unit in the face of any outside pressures. Any close affiliation with other such units was based primarily upon linguistic affinity and territorial contiguity, although religious ties might sometimes exist (Holder 1970:35).

After the smallpox pandemic of 1780-81, the traditional village pattern became disrupted. Geographic mobility of the Arikara greatly increased during the following decades (Lehmer and Jones 1968). Finally in the 1800's, survivors of earlier villages coalesced to form new villages, though these later settlements were not as harmonious as in previous times. Language diversity hampered communication (Thwaites 1904:188); disputes for power became common among the remaining chiefs (Nasatir 1952:299). Apparently earlier villages had maintained sufficient autonomy to develop linguistic variations. Factors as kinship relationships reduced the frequency of emigration and immigration between Arikara villages until forced by necessity. A net migration of zero appears to be a reasonable assumption for the Larson population.

The life table methodology was selected for analysis of the Larson population. The opportunities for hypothesis testing and for more complete description of population mortality experiences are definite advantages of this approach.

CHAPTER IV

VITAL STATISTICS AND POPULATION SIZE

The aims of paleodemographic reconstruction are to ascertain vital statistics and total size of earlier populations. This investigation's first objective is to examine the mortality experiences of an Arikara population during the years A.D. 1750-1781. The demographic methodology selected for analysis of the Larson population is construction of life tables. Preconditions and assumptions of this approach have previously been specified. Limitations are inevitable; yet, because the biological data can be richly supplemented by archaeological and historical information, control of the variables is greatly enhanced.

Demographic data presented for both sexes of the Larson population include mortality curves (dx), survivorship curves (lx), age-specific probability of death (qx), and life expectancy (ex). Crude death rates are calculated from the life tables. Population differences are determined by comparison of crude death rates and mortality curves with other relevant populations.

Possible causes of the Larson mortality pattern are discussed, and an attempt is made to identify areas of the cemetery which contain burials caused by an epidemic. Vital statistics, recalculated with elimination of these epidemic skeletal deposits, allows assessment of the distortion in life tables produced by an epidemic. The final objective is to estimate the number of occupants in the Larson village.

I. BASIC DATA AND LIFE TABLE COMPUTATIONS

Basic data for the calculation of vital statistics of the Larson populations is derived from 680 skeletons. Sex and age distributions of this sample are presented in Table 3. A total of 706 individuals were recovered during excavations; skeletal remains of 26 are extremely incomplete and were not ageable by the criteria applied. No compensation was made to correct for missing data because unaged specimens include both adult and subadult age classes and do not significantly alter the age distribution of the sample.

Computation procedures necessary for construction of the abridged life tables developed in this investigation follow guidelines outlined by Ascádi and Nemeskéri (1970).

The first column of the life table is x, the age categories. All age intervals, except the first two, are five years in length; the first is a one-year interval (ages 0-1); total age span of the second is four years (ages 1-4).

The second element is Dx, the actual number of individuals recorded as dying in each age interval. Table 3 provides this information. Since sexing techniques were not applied to the very young, data for the first two age intervals of the separate sex life tables were supplied by halving the total observed count. In case of an odd number for the total count (i.e. the number of individuals in age category 1 equals 255), the extra person was arbitrarily assigned to males. This procedure provides no information concerning differential sex mortality during the initial five years of life; however, it does facilitate computations. Two forms of evidence support legitimacy of this practice:

TABLE 3

AGE AND SEX DISTRIBUTION OF SKELETONS
FROM THE LARSON SITE

Age Interval	Male	Female	Total Number
0-1	--	--	255
1-4	--	--	102
5-9	6	9	57
10-14	6	8	21
15-19	17	27	44
20-24	11	15	26
25-29	18	10	28
30-34	30	12	42
35-39	22	20	42
40-44	11	8	19
45-49	11	8	19
50-54	5	7	12
55-59	5	8	13
Sample Total	142	132	680

201

113 88 680

adults

1. The Larson adult burial sex ratio does not differ significantly from a 1:1 ratio. If a high differential sex mortality rate occurred during childhood, the adult sex ratio would not be expected to approximate a 1:1 ratio.
2. Equal sex ratios were observed for subadults in several Indian tribes of the northern Plains area during the reservation period (Wissler 1939). This suggests similar mortality experiences.

The number of male and female dead in age categories 5-9 and 10-14 for the life tables were determined from the number of sexed skeletons, although not all specimens were actually sexable. In order to keep the relative number of dead constant, unsexed skeletons were proportioned according to the observed sex ratio in each age interval. Presumably male and female dentitions (sexing is by dental discriminant) were equally exposed to the hazards of preservation such that the perceived sex ratio reflects differential survival rates. However, chance could be responsible, especially for age interval 5-9 where many remain unsexed.

From the *Dx* values, *dx* is calculated to express the percentage of the population dying in each age category. The *dx* value represents the percentage of the total skeletal collection (680) which died in each age interval. Calculation requires the formula:

$$dx = \frac{Dx}{\sum_{x=0-1}^{w} Dx}$$

w = maximum age attained, in this case age category 55-59

x = the initial age category (0-1)

The *dx* values form the mortality curve of the population.

The lx shows survivorship, the percentage of survivors (of each cohort) remaining to enter the respective age categories. The first lx (l_{0-1}) is assigned a value of 100 (percent). Calculation of subsequent values is by subtraction of the percentage dying (dx) in each age interval:

$$l_{0-1} = 100$$
$$l_{1-4} = l_{0-1} - d_{0-1}$$
$$l_{5-9} = l_{1-4} - d_{1-4}$$

The probability of death for individuals of each age is qx. This statistic allows examination of age-specific mortality as it expresses the chances of individuals in the age intervals of dying before reaching the next x category. The value qx is the quotient determined by dividing the percentage dying (dx) by the percentage of survivors (lx) entering each age interval:

$$qx = \frac{dx}{lx} \quad \text{hence} \quad q_{0-1} = \frac{d_{0-1}}{l_{0-1}}$$

The value Lx is the total number of years lived in each age interval. The formula allowing calculation for all but the first two Lx values is:

$$Lx = \frac{5\ (lx + lx+5)}{2}$$

$$\text{so} \quad L_{5-9} = \frac{5\ (l_{5-9} + l_{10-14})}{2}$$

$$\text{and by definition} \quad L_{55-59} = \frac{5\ (l_{55-59})}{2}$$

The value *Lx* depends on survivorship (*lx*) and is calculated with the assumption that deaths are evenly distributed throughout each 5-year interval. During the first year of life, however, deaths occur most frequently in the early months. Ascádi and Nemeskéri (1970:64) suggest two formulas to account for this uneven time distribution of deaths:

$$L_{0-1} = 0.2\ l_{0-1} + 0.8\ l_{1-4}$$

$$L_{1-4} = 0.34\ l_{0-1} + 1.184\ l_{1-4} + 2.782\ l_{5-9}$$

The total number of years lived by survivors is *Tx*. Derivation of T_{0-1} is by summing all *Lx* values:

$$T_{0-1} = \sum_{x=0-1}^{w} Lx$$

Succeeding figures are computed by subtracting *Lx* from *Tx*:

$$T_{1-4} = T_{0-1} - L_{0-1}$$

$$T_{5-9} = T_{1-4} - L_{1-4}$$

and by definition $T_{55-59} = L_{55-59}$

The values *Lx* and *Tx* are of minor importance for description of population mortality (though *Lx* does allow determination of population age structure--see Buikstra 1972) but are essential for completing the life table.

The final life table series is life expectancy (e_x^o), the average number of years remaining to be lived by individuals entering each age interval. Derivation is by the formula:

$$e_x^o = \frac{Tx}{lx}$$

Life tables for the Larson population are given in Table 4, a composite life table (sexes combined); Table 5, the female life table; and Table 6, the one for males. To simplify examination of the Larson population's mortality profile, graphic representations of the essential life table functions are included in later discussions.

TABLE 4

ABRIDGED LIFE TABLE FOR THE LARSON POPULATION
(SEXES COMBINED)

Age (x)	Distribution of Deaths: No. (Dx)	Distribution of Deaths: Percent (dx)	Survivors (lx)	Probability of Death (qx)	Total No. of Years Lived in Each Age Category (Lx)	Total after Lifetime (Tx)	Life Expectancy (e^ox)
0	255	37.50	100.00	.375	70.00	1373.12	13.73
1-4	102	15.00	62.50	.240	240.15	1303.12	20.85
5-9	57	8.38	47.50	.176	216.55	1062.97	22.38
10-14	21	3.09	39.12	.079	187.88	846.42	21.64
15-19	44	6.47	36.03	.180	163.98	658.54	18.28
20-24	26	3.82	29.56	.129	138.25	494.56	16.73
25-29	28	4.12	25.74	.160	118.40	356.31	13.84
30-34	42	6.18	21.62	.286	92.65	237.91	11.00
35-39	42	6.18	15.44	.400	61.75	145.26	9.41
40-44	19	2.79	9.26	.301	39.33	83.51	9.02
45-49	19	2.79	6.47	.431	25.38	44.18	6.83
50-54	12	1.76	3.68	.478	14.00	18.80	5.11
55-59	13	1.91	1.92	.995	4.80	4.80	2.50

TABLE 5

ABRIDGED LIFE TABLE FOR LARSON FEMALES
A.D. 1750-1781

x	Dx	dx	lx	qx	Lx	Tx	$e^{o}x$
0-1	127	37.46	100.00	.375	70.03	1305.79	13.06
1-4	51	15.04	62.54	.240	240.20	1235.76	19.76
5-9	34	10.03	47.50	.211	212.43	995.56	20.96
10-14	12	3.54	37.47	.094	178.50	783.13	20.90
15-19	27	7.96	33.93	.235	149.75	604.63	17.82
20-24	15	4.42	25.97	.170	118.80	454.88	17.52
25-29	10	2.95	21.55	.137	100.38	336.08	15.60
30-34	12	3.54	18.60	.190	84.15	235.70	12.67
35-39	20	5.90	15.06	.392	60.55	151.55	10.06
40-44	8	2.36	9.16	.258	39.90	91.00	9.93
45-49	8	2.36	6.80	.347	28.10	51.10	7.51
50-54	7	2.06	4.44	.464	17.05	23.00	5.18
55-59	8	2.36	2.38	.992	5.95	5.95	2.50

TABLE 6

ABRIDGED LIFE TABLE FOR LARSON MALES
A.D. 1750-1781

x	Dx	dx	lx	qx	Lx	Tx	$e^{o}x$
0-1	128	37.54	100.00	.375	69.97	1439.90	14.40
1-4	51	14.96	62.46	.240	240.10	1369.93	21.93
5-9	23	6.74	47.50	.142	220.65	1129.83	23.79
10-14	9	2.64	40.76	.065	197.20	909.18	22.31
15-19	17	4.99	38.12	.131	178.13	711.98	18.68
20-24	11	3.23	33.13	.097	157.58	533.85	16.11
25-29	18	5.28	29.90	.177	136.30	376.27	12.58
30-34	30	8.80	24.62	.357	101.10	239.97	9.75
35-39	22	6.45	15.82	.408	62.98	138.87	8.78
40-44	11	3.23	9.37	.345	38.78	75.89	8.10
45-49	11	3.23	6.14	.526	22.63	37.11	6.04
50-54	5	1.47	2.91	.505	10.88	14.48	4.98
55-59	5	1.47	1.44	1.021	3.60	3.60	2.50

II. MORTALITY AND SURVIVORSHIP

Mortality curves (*dx* values) for the Larson population are shown in Figure 5. The combined sex curve reveals an excessively high percentage of deaths in the first year of life; 37.5 percent of the Larson burials are assigned this age category. During childhood, mortality rapidly decreases with increasing age but remains high relative to adult mortality. The adolescent years of 10-14 were the healthiest period for Arikara subadults; only 3 percent of the burials fall within this age span. Mortality increases in frequency for individuals entering young adulthood (ages 15-19), a rise possibly reflecting the adoption of adult activities. Young adults, aged 20-29, experienced low mortality, when compared to adults in general, although fatalities do increase with age during this decade. Maximum mortality peak of adult deaths is between ages 30-39 years. In the later adult years, the mortality curve slopes downward; only 9.3 percent of the population's deaths involved individuals older than 40.

Sex differences in the age distributions at death suggest differential mortality at all ages between 5 and 35. During the subadult years (5-15), the mortality curves show a slightly higher percentage of female deaths relative to males. Both sexes increase in the percentage of deaths at ages 15-19, though again female deaths are more frequent--8 percent as against 5 percent for males. The actual peak of adult female mortality is during the ages of 15-19. The percentage of female deaths continues to remain higher than that of males in the early 20's. Many female fatalities in these young-adult years probably directly relate to complications of pregnancy

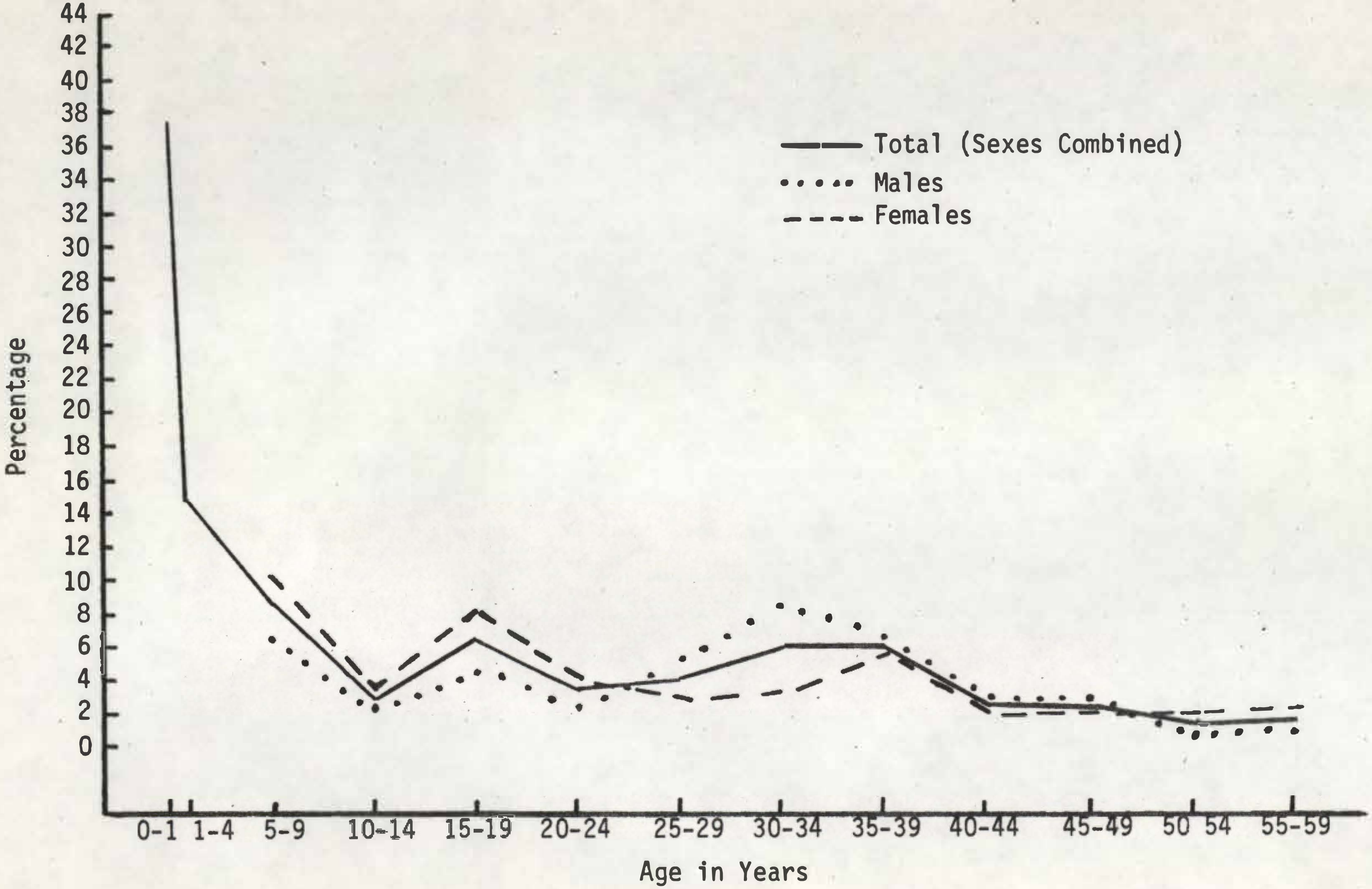

Figure 5. Age distribution of male and female deaths (mortality curves) in the Larson population.

and childbirth. The percentage of male deaths rises in frequency beginning at age 25 and ascends to the maximum adult male mortality peak (8.8 percent) at ages 30-34. On the contrary, the distribution curve for females aged 25-34 descends and remains comparatively lower. A second mode (5.9 percent) in the female percentage distribution of deaths occurs at ages 35-39. After 35, mortality curves for males and females become similar.

Figure 6 plots the percentage of the Larson population surviving to each age interval (lx), until complete extinction--the survivorship curves. The slope of the curve descends most rapidly during the first five years due to the high number of deaths in infancy and early childhood. By age 5, less than half (47.5 percent) of each cohort (number of births yearly, in this case equal to 100 percent) remained alive. At age 20, 29.6 percent of all individuals born in the Larson population were still living; 9.3 percent survived to age 40, and only 1.9 percent attained the age of 55.

Differential survivorship patterns for males and females caused an unequal sex ratio in the Larson population. The survivorship curves indicate that during all ages between 5 and 35 years, males outnumbered females. For instance, at age 25, 29.9 percent of the males were alive, while only 21.6 percent of the females remained. Only after the increase in the number of male deaths at ages 30-34 does the proportion of surviving males and females equalize, although in the final decade of life, a slightly higher percentage of females were living.

Graphic illustration of the probabilities of death is given in Figure 7. The curve forms a rough U shape, a reflection of a high

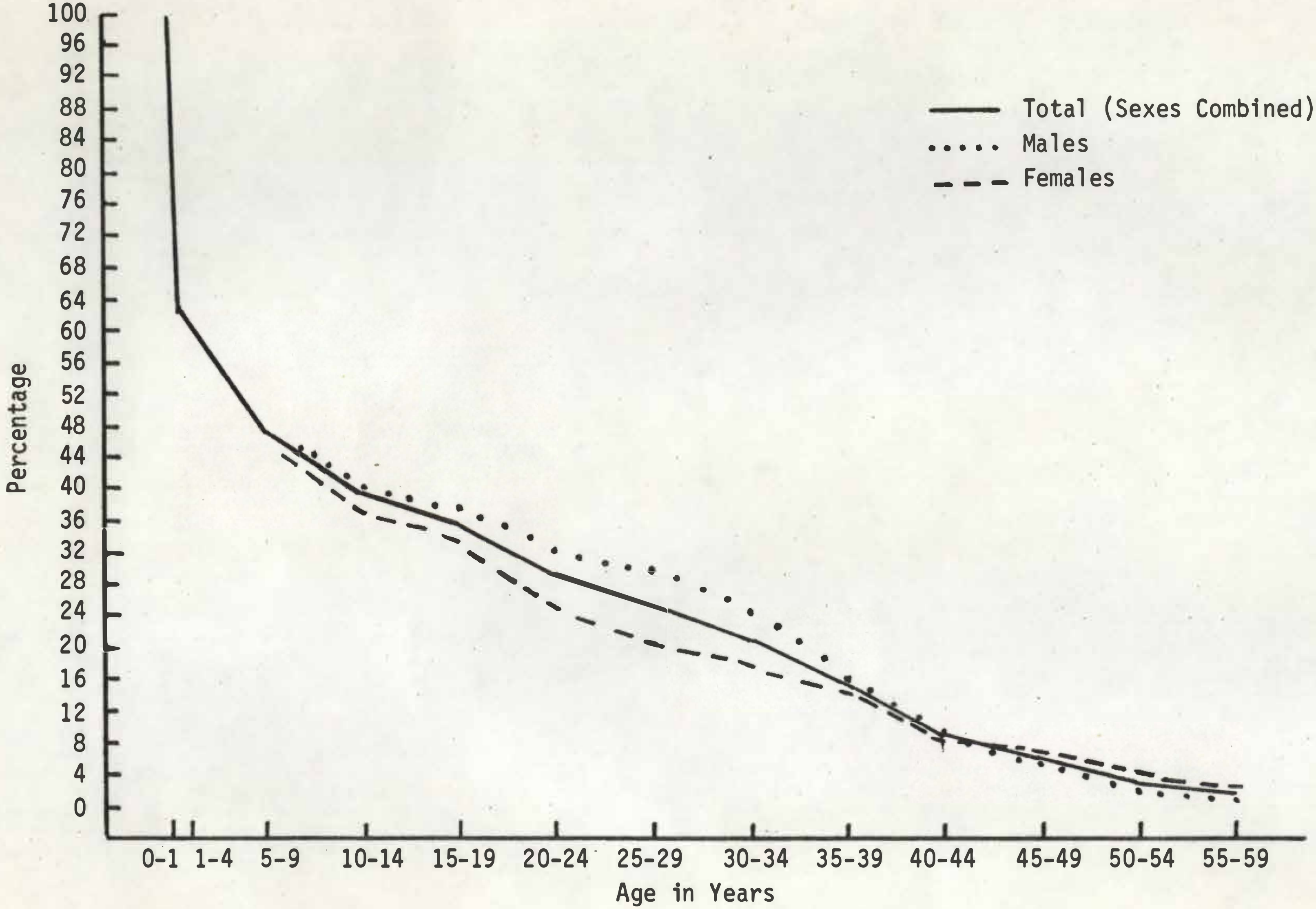

Figure 6. Survivorship of the Larson population.

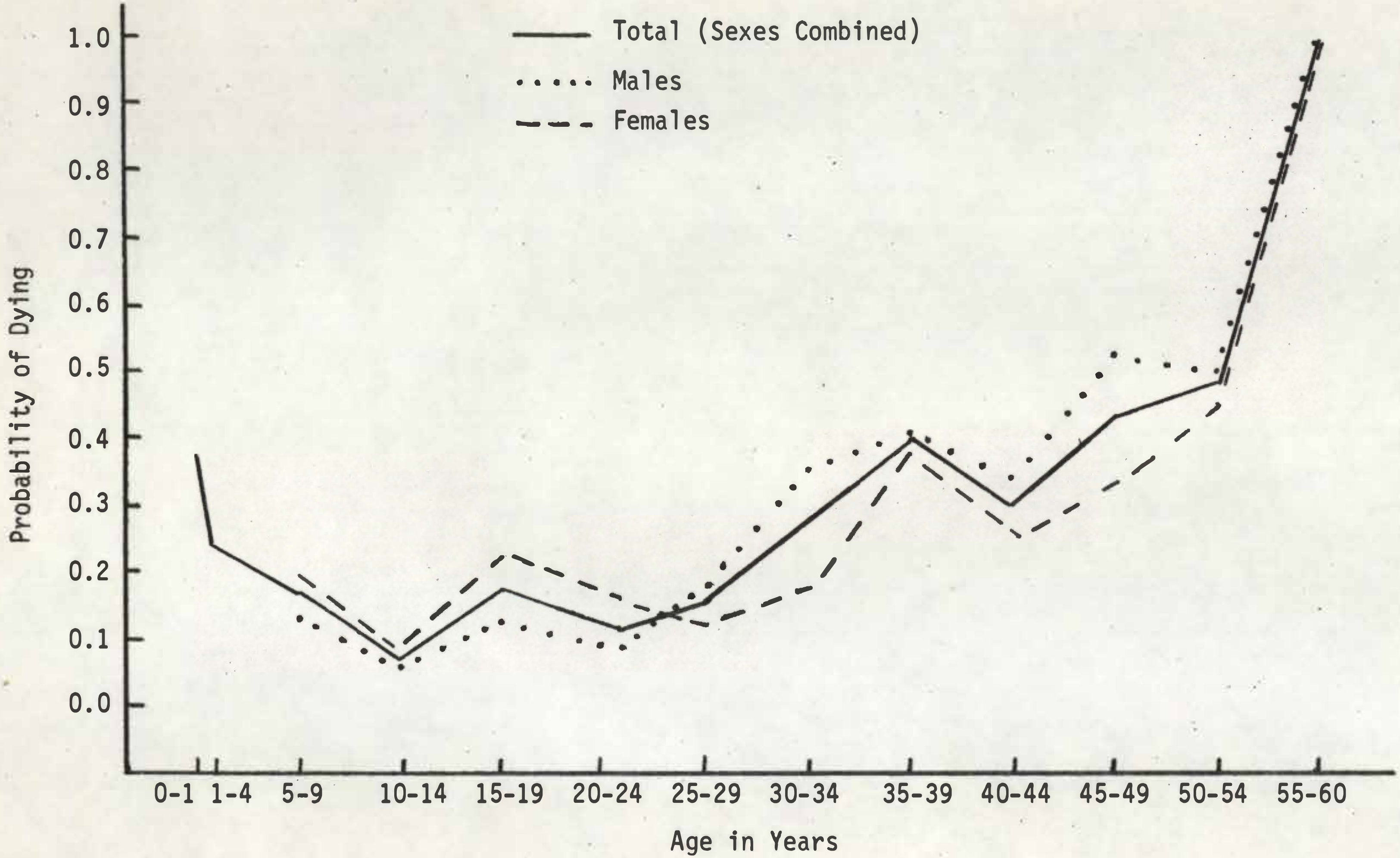

Figure 7. Probabilities of death in the Larson population.

probability of dying in the beginning and ending years of the life span. Lowest probability of death (.079) is for individuals of both sexes aged 10-14, definitely the healthiest segment of the population. After this minimum, the *qx* values begin to rise as chances of death increase with age.

Male subadults had a lower probability of death than females, a trend which persisted into early adulthood. For instance, males aged 20-24 had excellent chances of survival, having had the second-lowest *qx* value (.097) of all ages. After 25, females have a lower probability of death. Noticeable sex differences in this indicator of age-specific mortality occur for individuals of the following age intervals:

1. Of females aged 15-19, 23.5 percent died before attaining the age of 20 (qx = .235); only 13.1 percent of the corresponding males died (qx = .131).
2. At age 30-34, 35.7 percent of the males reaching this age died; 19 percent of the females died.
3. Of males surviving to age 45-49, 52.6 percent died during this age interval; for females, 34.7 percent died.

The final life table function--life expectancy--is plotted in Figure 8. Male life expectancy at birth (e^{o}_{0-1}) is 14.4 years, approximately 1.3 years longer than for females (13.1 years). For individuals surviving through the period of high infant mortality, life expectancy increases considerably. Life expectancy for 5-year-old males is an additional 23.8 years; for females it is 21.0 years, nearly three years less than for males. However, by age 20, this inclination for greater male expected longevity reverses. Surviving females could expect to live more years than corresponding

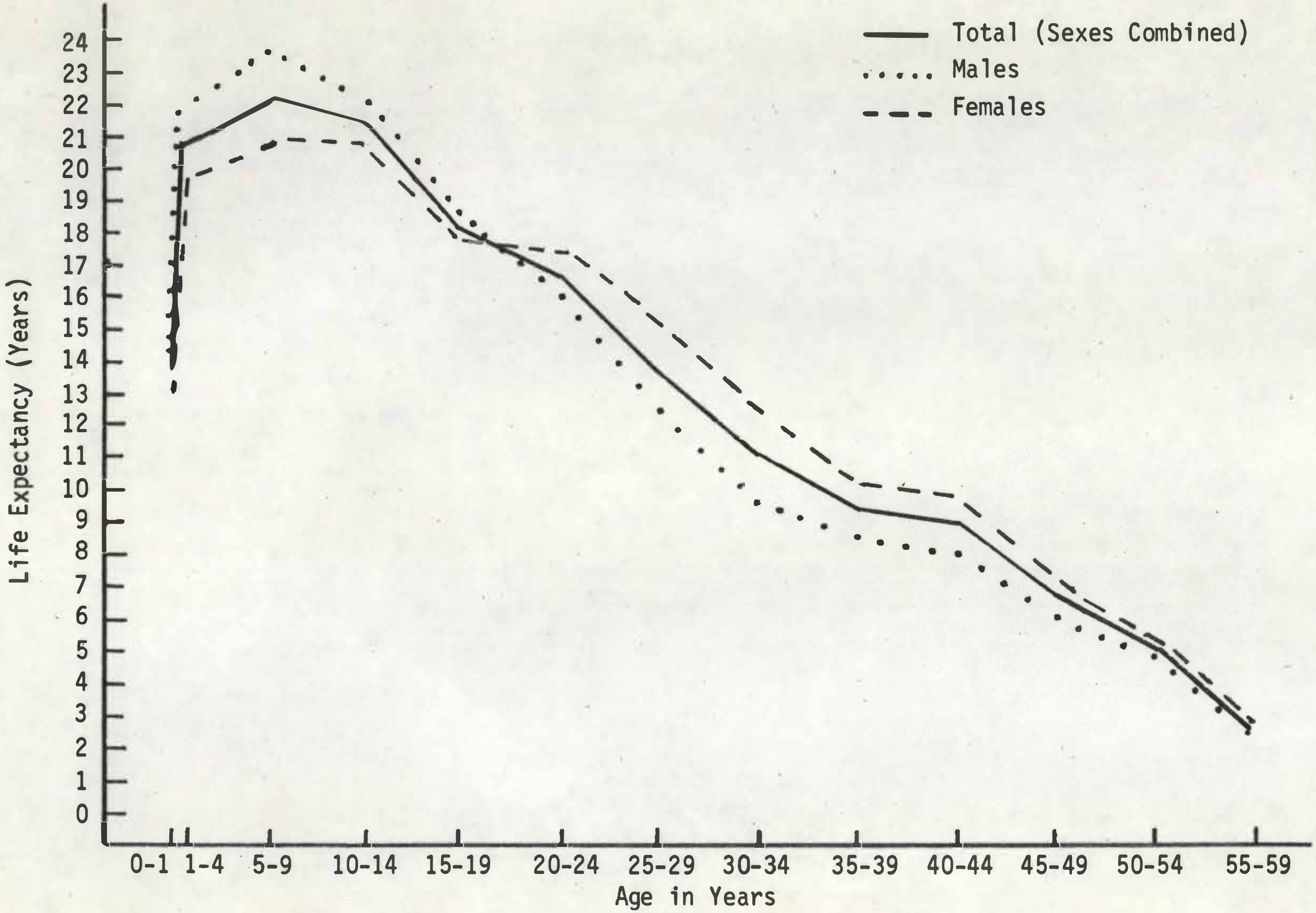

Figure 8. Life expectancy of the Larson population.

males. Twenty-year-old females could expect to survive another 17.5 years (total average life span = 37.5 years); male average expectance was 16.1 years (total average life span = 36.1 years). By age 30, remaining males were likely to live an average of 9.8 years more, females another 12.7 years. Expectation of life at age 40 still favored females by approximately two years; both sexes could anticipate an average of about nine more years.

Briefly summarized, the life table functions suggest the following basic points concerning mortality and longevity of the Larson people. The population suffered an extremely high infant mortality rate, which remained fairly high throughout childhood. Adolescents enjoyed good health and recorded the lowest probability of death of all age categories. Mortality then increased for young adults (15-19), especially for females. However, females fortunate enough to survive through this age and the early 20's could expect improved chances for survival when compared to males. A second mode in the female mortality curve is at ages 35-39. The greatest percentage of male deaths occurred in the fourth decade, especially ages 30-34. Of the total 680 individuals considered, only 13 (1.9 percent) are believed to have attained the age of 55.

III. SUBADULT MORTALITY OF THE LARSON POPULATION

Few paleodemographic investigations have presented detailed information concerning subadolescent mortality. However, for Larson this segment of the population suffered the majority of deaths. To examine subadult mortality more thoroughly, the age distribution of deaths in the Larson skeletal collection is given for ages birth to

14.5 years in Table 7 and graphically illustrated in Figure 9. Age intervals are recorded in two-year increments except the first, which is limited to the initial six months of life (0-0.5 years). In addition, Table 7 shows: (1) the number of individuals dying at each age, a total of 434; (2) the percentage dying in each age interval of the total number of subadults (these values are plotted in Figure 9); (3) the percentage dying of the total skeletal collection (equivalent to *dx* values).

The age distribution of Larson subadults shows that the greatest percentage of deaths involved infants less than 2.5 years old, especially neonatal mortality during the first six months of life. The curve then levels, although decreasing slightly with advancing age until reaching a minimum at ages 11 and 12. Relative to adult mortality, the subadult years (except adolescence) experienced higher mortality, the worst being the initial 2.5 years of life.

TABLE 7

AGE DISTRIBUTION OF SUBADULT DEATHS
(SEXES COMBINED)

Age Interval (Year)	Number	Percentage of Subadults	Percentage of Total Population
0.0-0.5	223	51.38	32.79
0.5-2.5	104	23.96	15.29
2.5-4.5	25	5.76	3.68
4.5-6.5	23	5.30	3.38
6.5-8.5	28	6.45	4.12
8.5-10.5	14	3.23	2.06
10.5-12.5	6	1.38	0.88
12.5-14.5	11	2.53	1.62
Total	434		

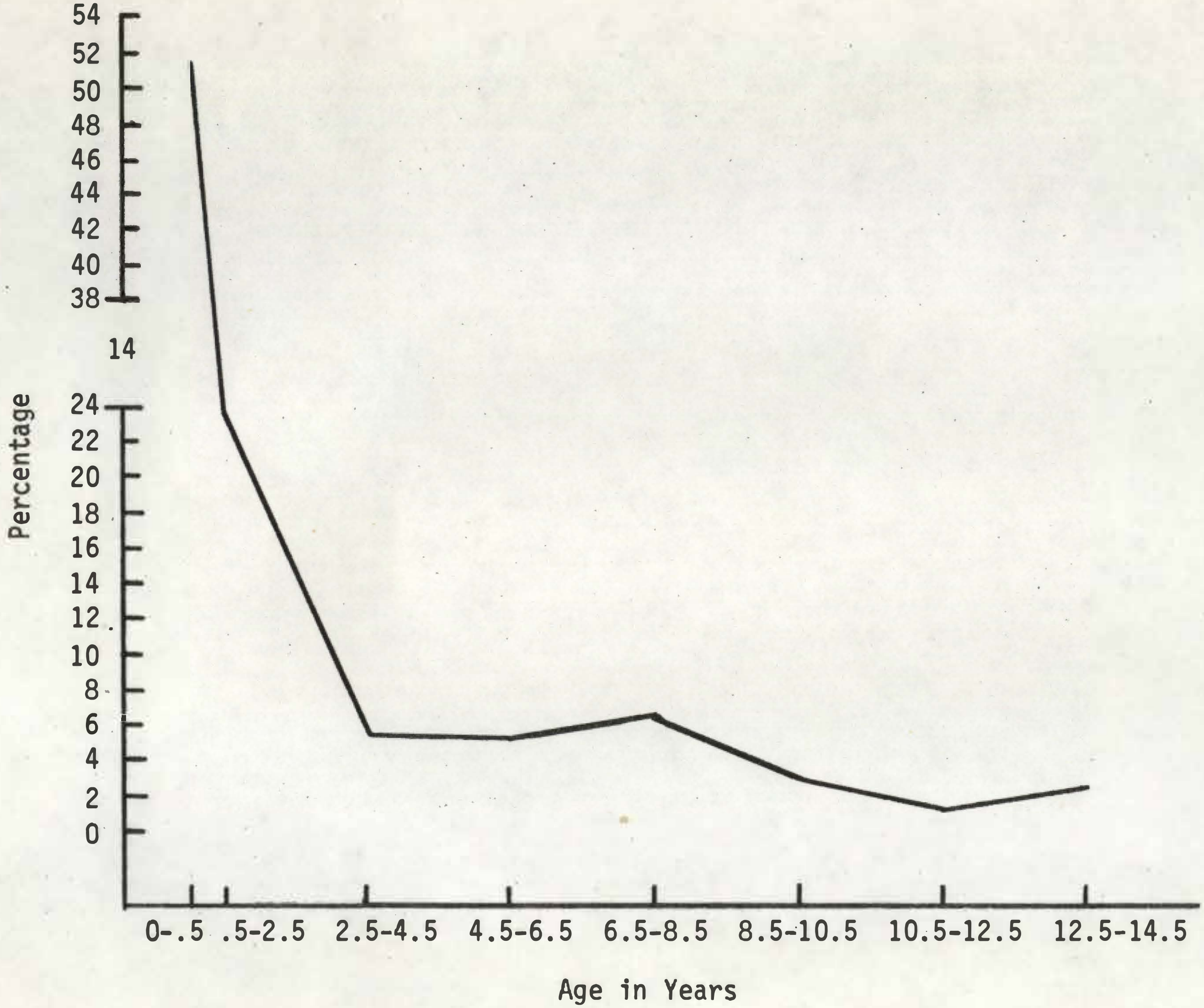

Figure 9. Subadult age distribution at death.

IV. INTERPOPULATION COMPARISONS

Life Expectancy at Birth

Life expectancy, as a measure of population longevity and health status, can be used to provide meaningful comparisons between groups. The most commonly utilized value is life expectancy at birth. Expectation of life at birth is given in Table 8 for several "world-wide" populations, including available data for aboriginal Amerindian populations. The table is modified from Ubelaker (1974:64). (See this reference for a listing of the original sources and data limitations.)

TABLE 8

LIFE EXPECTANCY AT BIRTH IN SEVERAL WORLD POPULATIONS

Populations	Dates	Life Expectancy (years)
Larson	A.D. 1750-1781	13.7
Indian Knoll, Kentucky	3000 B.C.	18.6
Nubia, Egypt	A.D. 1050-1600	19.2
Nanjemoy, Ossuary I	A.D. 1500-1600	20.9
Nanjemoy, Ossuary II	A.D. 1500-1600	22.9
Ancient Greeks	670 B.C.-A.D. 600	23.0
Texas Indians	A.D. 850-1700	30.5
European Ruling Families	A.D. 1480-1579	33.7
U.S. Caucasian	A.D. 1800	30.0-35.0
U.S. Negro	A.D. 1900	33.8
English	A.D. 1000-1100	35.3
India (Females)	A.D. 1951-1960	40.6
India (Males)	A.D. 1951-1960	41.9
Pecos Pueblo	A.D. 800-1700	42.9
England and Wales (Males)	A.D. 1965-1967	68.7
England and Wales (Females)	A.D. 1965-1967	74.9

Modified from Ubelaker (1974:64).

The life expectancies in Table 8 are listed according to increasing size, an arrangement which emphasizes that life expectancy at birth in the Larson population was lowest of all considered. Even the early Indian populations such as Indian Knoll, Nanjemoy, Texas Indians, and Pecos Pueblo had substantially higher values than Larson. The Larson population was apparently exposed to stressful conditions causing early death (especially high infant mortality) which drastically lowered their life expectancy.

Mortality Curves of Populations in the Missouri Valley

Comparison of the Larson mortality curve with other similar, but not contemporaneous, Arikara populations in the Middle Missouri Valley allows examination of interpopulation differences. Demographic data determined from two other skeletal collections were reported by Bass, Evans, and Jantz (1971). These skeletal samples are: (1) the Leavenworth site (39CO9), an Arikara village dated A.D. 1803-1830 (sample size = 284); and (2) the Sully site (39SL4), 481 burials dated approximately A.D. 1700-1750 (Jantz 1973).

The percentage of deaths in each five-year age interval (dx values) for these populations is given in Table 9. The dx values form the mortality curves shown in Figure 10.

Examination of the mortality curves for the three Arikara populations indicates that the highest frequency of death was in the first five years of life. Sully, chronologically the earliest population and presumably the one least affected by postcontact environmental changes (as new diseases), has the lowest percentage of deaths in the first interval (45.5 percent); Larson has the most (52.5 percent).

TABLE 9

AGE DISTRIBUTION OF DEATHS IN THREE ARIKARA POPULATIONS (PERCENT)

Age Interval	Larson (dx)	Leavenworth (dx)	Sully (dx)
0-4	52.5	49.5	45.5
5-9	8.4	7.7	5.8
10-14	3.1	4.2	4.2
15-19	6.5	5.7	4.7
20-24	3.8	7.1	7.1
25-29	4.1	8.2	7.7
30-34	6.2	6.0	6.4
35-39	6.2	6.1	6.3
40-44	2.8	3.1	7.3
45-49	2.8	2.4	5.0
50-54	1.8	0.0	0.0
55-59	1.9	0.0	0.0

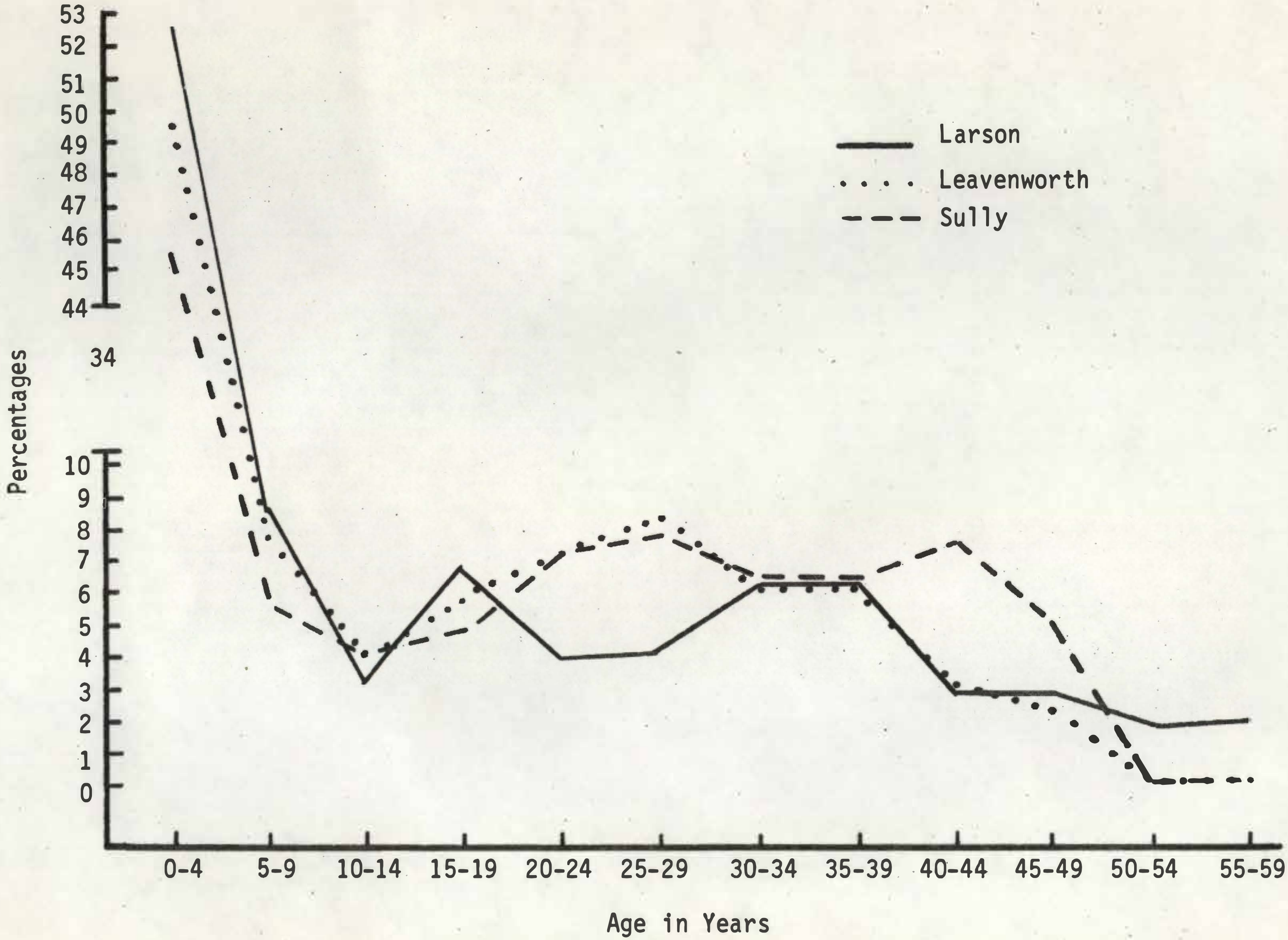

Figure 10. Mortality curves for three Arikara populations.

Curves for all three populations descend rapidly during childhood until reaching the period of minimum child mortality beginning at age 10. Fatalities then increase for young adults, aged 15-19, especially for Larson and Leavenworth. The major discrepancy in the curves is in the third decade. The Leavenworth and Sully populations experienced the highest frequency of adult deaths at ages 25-29; for Larson the mode of adult deaths was between 30-39 years. After 40, Leavenworth and Larson decreased in the percentage of deaths; actually mortality increased, but the number of survivors had greatly diminished. Sully does have a mode at ages 40-44.

The temporally earlier Sully population shows certain effects of less severe environmental stress--the lower frequency of subadolescent deaths, a decreased percentage of young adult deaths, and a peak of adult deaths at age 40-44 (presumably an "old age" mode not observed in the other curves). Characteristics of the later populations suggest more intense selection pressures operating on subadults and also young adults (for Larson, many of these deaths involve females and probably correspond with the increased infant mortality).

Exactly why a major difference between Larson and the other populations appears in the third decade is difficult to determine. Possibly the more intense selection against children and young adults in the Larson population eliminated the less fit, so that many of those remaining were capable of surviving through the following decade.

There are two sources of data distortion which may limit validity of these comparisons. First, in order to examine the mortality profile of Leavenworth and Sully in five-year increments, the basic data required smoothing (see Bass, Evans, and Jantz 1971:160).

The second is possible differences in ageing techniques. Adult ages for both sexes of the Leavenworth and Sully populations was determined by the McKern and Stewart (1957) male pubic symphysis standards, since female standards were not yet available. According to Gilbert (1973:39), "complete pubic maturation in the female occurs on the average ten years later than in the male; fully mature female pubes will be underaged by the male standard." This tendency may have the effect of lowering the age interval of the maximum adult mortality peaks and could explain population differences observed in the percentage of deaths between ages 20-30.

V. CRUDE DEATH RATE

The crude death rate (*m*) expresses the total number of individuals dying per 1000 per annum and is useful as it provides a general assessment of population mortality. "The figure is a direct reflection of overall life expectancy and can present evidence for population decline, equilibrium, or expansion when considered in relation to the birth rate" (Ubelaker 1974:65).

The crude death rate of a stationary population can be determined directly from the life table. Acsádi and Nemeskéri (1970:44, 67) calculate the death rate as the reciprocal of life expectancy at birth:

$$m = \frac{1}{e^0_{0-1}}$$

The Larson population's life expectancy at birth equals 13.73; the crude death rate is 72.8. Compared to crude mortality rates

estimated from other skeletal collections (see Table 10), Larson is the extreme. The Larson population has the highest annual number of deaths of the populations considered, including the Leavenworth and Sully Arikara populations. However, the especially high crude death rates of the later Arikara populations are not altogether unrealistic when compared with reservation Indian mortality rates. Wissler (1939:60) recorded mortality rates as high as 67 per 1000 for Northern Plains Indians during the years A.D. 1895-1929.

Crude death rates of 73 and 63 for Larson and Leavenworth, respectively, undoubtedly exceeded the Arikara fertility level. The crude birth rate--the yearly number born per 1000 total population--in many recent nonwesternized world populations ranges between 40 and 50 per 1000 (De Jong 1972). Perhaps more analogous are the birth rates reported by Wissler (1939) for reservation Indians. Maximum crude birth rate observed was 53 per 1000; average for the Plains tribes was 44.

TABLE 10

CRUDE DEATH RATES CALCULATED FROM NORTH AMERICAN SKELETAL COLLECTIONS

Site	Location	Death Rate
Nanjemoy, Ossuary II	Maryland	44
Nanjemoy, Ossuary I	Maryland	48
Sully	South Dakota	54
Indian Knoll	Kentucky	59
Leavenworth	South Dakota	63
Larson	South Dakota	73

Modified from Ubelaker (1974:66).

The interrelationship between the birth and death rates allows calculation of the rate of natural population growth (Acsádi and Nemeskéri 1970:68):

$$e = n - m$$

e = the rate of growth per 1000 per annum
n = crude birth rate
m = crude death rate

If the Larson people are assigned the average Plains Indian birth rate of 44 and also the maximum of 53 and the natural growth rate is computed, values for *e* (see Table 11) range between -20 and -29 per 1000 per year. In other words, mortality exceeded fertility; the population decreased in size by a rate of 2 to 3 percent per year during the 30 years of residence at the Larson site.

TABLE 11

CALCULATION OF THE LARSON RATE OF NATURAL GROWTH

Hypothetical Crude Birth Rate (n)	Larson Crude Death Rate (m)	Growth Rate (e)
44	73	-29
53	73	-20

Both archaeological data and historical sources testify to a rapid decline of the Arikara population during the Post-Contact period. Deetz (1965:32) reports that "examination of site reports dealing with Arikara sites of the seventeenth and eighteenth centuries shows a general trend toward reduction of house size from the earliest to the latest sites . . ."--a change probably resulting from depopulation.

Early European documentation of the size of the Arikara nation confirms that originally a large Arikara population existed in the Middle Missouri Valley. According to Trudeau (Nasatir 1952:299), "In ancient times the Ricara nation was very large; it counted thirty-two populous villages......." Tabeau (Abel 1939:124) also mentions the number of villages, stating that originally 18 fairly large ones were located along the Missouri. These accounts, though differing in actual number, both describe a large Arikara population. The Arikara, prior to decimation, must have listed at least 15,000 people (Holder 1970:85). But times changed:

> This nation formerly so numerous, and which according to their reports, could turn out four thousand warriours [sic], is now reduced to about five hundred fighting men . . . (Nasatir 1952:299).

By 1804, the Arikara were reduced to three villages (Abel 1939). Will and Hyde (1917:47) gave population estimates of 2600 in 1804; by 1859, only 109 earth lodges existed; and in 1904, 380 Arikara remained.

Excavations of the Larson village support the biological data for depopulation at this particular site. Successive rebuilding of the earth lodges reduced the perimeters and sizes of the structures (Bowers n.d.f). Hoffman (n.d.a) reports two fortification ditches for Larson, the inner being stratigraphically most recent:

> As a rough generality, our test suggests a marked contraction in living area (and population?) through time, as well as some strong stimulus that forced the later peoples to rebuild within a prescribed area (Hoffman n.d.a).

Biological data suggest a decline in the number of villagers at Larson through time; mortality exceeded fertility. In one sense, this poses an interesting dilemma. Such evidence invalidates the stationary population model used to determine the statistics thus far produced. Exactly how much error is introduced is presently unknown. Certainly the estimated crude mortality rate is in accordance with with archaeological and historical information concerning the Arikara and, in particular, the Larson site. Ecological and behavioral stress factors caused the Arikara population to decline in size during the 30 years of residence at the Larson site.

VI. CAUSES OF THE MORTALITY PROFILE

Two sources of information provide evidence for causes of death in the Larson population: (1) historic documentation of Arikara behavioral patterns and diseases, and (2) pathological skeletal material recovered at Larson. Major determinants for the Larson mortality profile are categorized for discussion into the following four topics: famine, warfare, childbirth and obstetrical care, and disease.

Famine

Starvation, due to the failure of food crops and unabundance of buffalo and wild game, is reported to have caused some Arikara deaths. Tabeau (Abel 1939:72), an early trader, recorded that:

> There are instances of families and of entire tribes, which not withstanding their precaution of drying their meat against a shortage, have experienced horrible famine and have sometimes died of hunger.

Intertribal Warfare

The sedentary horticultural villages were subject to attack by the more nomadic tribes of the Missouri Valley. Many early historical sources mention warfare excursions and raids by Crow, Assiniboin, and especially the Dakota Sioux against the Arikara, and vice versa (Abel 1939; Brackenridge 1904; Larpenteur 1962; Thwaites 1904).

Will and Hyde (1917:49) note that the Sioux were not living near the Upper Missouri River in A.D. 1743 but arrived in abundant numbers between the years 1750 and 1770, a date of arrival which is in time to have affected the Larson people.

Krause (1972) considers village defense against raids to be a paramount concern of the Arikara:

> The villagers lacked the personnel and the material resources to organize large masses of warrior troops and to sustain extended search and destroy campaigns.
>
> For horticultural peoples the demands made by inter-tribal warfare were those of defense. These demands put a premium on manpower massed at the point of attack . . . (Krause 1972:109).

Probably some of the Larson male deaths are attributable to warfare (the author does recall one skeleton having a projectile point lodged in a vertebral centrum).

If intertribal warfare was centralized around the earth lodge village, males lost in battle would probably be buried in the cemetery. On the other hand, if Arikara males were involved in raids and battles at a distance, males killed might not be recovered for burial in the traditional area. A deficiency in the number of cemetery males would be expected. To test these possibilities, a chi-square test for goodness of fit was employed to compare the observed adult sex ratio (130 males to 115 females; adulthood implies older than 15 years) to

a theoretical 1:1 sex ratio. Results are not significant (chi square = .918; probability = 0.5-0.1); the null hypothesis that the observed sex ratio fits a 1:1 ratio is accepted. This supports the assumption that the cemetery is an unbiased representation of the total number of deaths of the Larson adults. Population members were probably not excluded from burial in the cemetery for social or cultural reasons such as warfare. It also shows that if the Larson males were involved in much fighting, it was near their homes.

Childbirth and Obstetrical Care

The high infant mortality rate and increased frequency of young female deaths may be partially explained by complications caused by childbirth and associated poor obstetrical care. Little available evidence pertains directly to the Arikara; however, a study by Aberle (1932) discussing reasons for infant and child mortality among Indians of the Southwest is relevant. Aberle examined two Pueblo populations in New Mexico from 1885 to 1930 which were following traditional tribal practices for delivery and postnatal infant care.

> The very high mortality among Indian infants and children must be due to many causes; but probably the most important cause is ignorance concerning the treatment of women during parturition and the care and feeding of children (Aberle 1932:347).

It is highly unlikely that the Larson people differed greatly as to their general knowledge level of maternal and infant care.

Aberle (1932:347) also reports a stillbirth rate of 1.6 percent for the Pueblo Indians. To suspect a similar or even higher rate for the Larson population is not unrealistic. Kryzwicki (1934:94-95) observed stillbirth rates elevated as high as 5 and 6 percent among populations undergoing rapid decline in size due to European contact.

Diseases

Arikara communities of the postcontact period were exposed to several new diseases which, due to the people's high susceptibility, are considered to be the major cause of population decline. Communicable diseases included measles, chickenpox, whooping cough, cholera (Jarcho in Lehmer and Jones 1968:70), venereal disease (Denig 1961:54), and especially smallpox.

Living conditions and sanitation habits of the Arikara proved most conducive to outbreaks of disease:

> The whole of the Arikara village, both within and without their habitations, presents a disgusting appearance. The spaces between the huts are seldom if ever cleaned, animal and vegetable substances in every state of putrefaction are scattered about, and the consequence of this is fluxes, dysentaries, scurvy, and other diseases prevail in the warm months, which sweep off numbers of every age and sex (Denig 1961:54).

> The rains had rendered their village little better than a hog pen . . . inattentive to the cleanliness so necessary to health, where a great mass of beings are collected in one place; and we need not be surprised at the frequency of desolating plagues and pestilence (Brackenridge 1904:114).

> Their children die off in far greater numbers than those of the roving tribes from diseases arising from the filthy state of their abodes, from cholera infantum in the season of green corn, and from the impure air in their dark and damp hovels (Denig 1961:54).

The introduction of smallpox into the valley caused extremely disastrous consequences for indigenous populations:

> The disease (smallpox epidemic 1780-1781) raged over the upper Missouri, the Saskatchewan and Columbia river and Great Slave Lake region, paralyzing the fur trade for two years . . . Starting on the Missouri river the previous year, this epidemic is said to have destroyed from a third to a half of the Indians in the area which it devastated (Stearn and Stearn 1945:47).

Indian populations had little natural resistance against smallpox (Catlin 1926; Chittenden 1935; Denig 1961; Larpenteur 1962).

> Deaths were almost instantaneous. The victim was seized with pains in the head and back, and in a few hours was dead. The body immediately turned black and swelled to thrice its size. Nearly everyone who was attacked died (Chittenden 1935:614).

> Among the Indians, even in the nineteenth century when some immunity had already been acquired by this race, we find a case fatality among some tribes during certain of the epidemics as high as from 55% to over 90% (Stearn and Stearn 1945:15).

The smallpox epidemic of 1780-1781 is believed to be the reason for abandonment of the Larson village and the cause of the unburied human skeletons in the earth lodges. Behavior of the Arikara and Mandan people during later smallpox epidemics illustrates probable events at Larson:

> All the Ree's that were encamped in the Mandan lodges, except a few that are sick, Moved down to the Island hoping to get rid of the small pox--the Mandans talk of Moveing to the other side of the river, 12 or 15 died today . . . .
>
> . . . .
>
> Mandans all crossed to the other side of the river to encamp--leaving all that were in the village, I keep no a/c of the dead as they die so fast that it is impossible . . . (Abel 1932:126).

> Several Men, Women, and Children that has been abandoned in the Village, are laying dead in the lodges, some out side of the Village, others in the little river not entered, which creates a very bad smell all around us . . . (Abel 1932:128).

Pathological skeletal material from the Larson site testifies to at least one other major killer of the population--tuberculosis. Eleven cases of skeletal tuberculosis, involving both sexes and adult and subadult age categories, have been identified in the skeletal collection (Smith n.d.). Young adults aged 18 to 29 accounted for seven of these observed cases.

Morse (1969:45) has synthesized much of the available literature concerning tuberculosis morbidity and mortality among reservation Indians of the early 1900's. His analysis indicates that the incidence

of bone tuberculosis equals 7 of every 100 cases of tuberculosis (other forms being pulmonary and lymph-node tuberculosis). If such statistics directly apply to the Larson population, we can expect (by proportion) as many as 157 deaths in the observed skeletal collection to be due to this cause.

In conclusion, it seems apparent that many factors were responsible for deaths of the Larson people. Disease especially was prevalent and increased mortality among the more vulnerable subadults. Yet, adults were by no means completely immune. "A married woman of this nation not only looks old but really is so at thirty years" (Denig 1961:61).

VII. DEMOGRAPHIC EVIDENCE FOR A SMALLPOX EPIDEMIC

The likelihood of an outbreak of smallpox among the Larson people poses the question as to whether demographic data can be used to test this possibility. Presumably the majority of the Larson burials are pre-epidemic and reflect normal mortality experiences extending over a 30-year time span. In the event that the Larson population was exposed to smallpox, some, and probably many, deaths followed. If these epidemic victims were distinguishable from normal burial deposits, it is likely that skeletal remains of the former would reflect a change in the mortality profile. Diagnostic characteristics caused by the epidemic include traits such as an increase in the crude death rate, or possibly an increased mortality rate for certain age segments of the population. That is, specific age classes--young or old--may have had a higher case fatality rate once contracting the disease and as such are disproportionately represented among the dead.

To return briefly to the discussion in the previous chapter, it was suggested that there are intracemetery differences in the relative dating of four defined areas. Burial location was dependent upon calendrical date; burials of a particular time period were, in general, grouped together rather than dispersed throughout the total cemetery. So, if any smallpox victims are buried in the cemetery (as distinct from the village), these are probably clustered in one of the defined areas (I, II, III, IV). An alternative explanation was also mentioned, that burial spatial location was determined according to societal status.

To resolve this dilemma and to attempt to identify the smallpox victims, two lines of research were applied: (1) By chi-square statistic, the burial sex ratio in each area was compared to a 1:1 ratio. (2) The age distribution of each cemetery area was compared with all other areas. In addition to the four cemetery divisions, skeletal material recovered from the village, designated Area V, was used for comparisons.

The burial sex ratio of these five areas was tested by chi-square to determine if each data set fits a 1:1 ratio. An equivalent number of males and females is more logically attained if burial spatial location was assigned on the basis of time, rather than by status. For instance, if societal status influenced burial location, it is conceivable that certain areas would have an excess or deficiency of a particular sex.

Table 12 lists the number of males and females represented in each cemetery area (I, II, III, IV) and the village (V), chi-square values, degrees of freedom, and probabilities of occurrence.

TABLE 12

CHI-SQUARE VALUES FROM COMPARISON OF THE OBSERVED SEX RATIO TO A 1:1 RATIO FOR THE VILLAGE AND CEMETERY SUBAREAS

Area	No. Males	No. Females	Chi-Square Value	Degrees of Freedom	Probability
I	16	19	0.26	1	0.9-0.5
II	39	25	3.06	1	0.1-0.05
III	28	30	0.07	1	0.9-0.5
IV	34	37	0.13	1	0.9-0.5
V	32	22	1.85	1	0.5-0.1

Note: The collective total represented does not include all individuals identified as to sex; some burials were recovered by local collectors and are of unknown spatial location.

Examination of this table indicates that none of the areas deviates from a 1:1 sex ratio at a 0.05 level of significance, which supports the premise that primarily time, and not status, directed burial location.

The next comparisons use the chi-square statistic to contrast the age distribution in each area with all others. Differences in the age distributions presumably reflect changes in age-specific mortality rates through time (if burial location is a function of time). If age-specific mortality rates remained constant throughout the period of cemetery use, all areas should have a similar age distribution.

Table 13 gives the number of individuals in the age classes of each of the five spatial locations considered and the percentage of deaths in these age categories. (These age intervals are increased in width to allow adequate sample sizes for chi-square comparison.)

TABLE 13

AGE DISTRIBUTION OF SKELETAL MATERIAL RECOVERED FROM FIVE LOCATIONS

Age Category	Area I		Area II		Area III		Area IV		Area V	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
0-4	104	70.7	72	51.4	66	50.4	97	55.7	10	14.7
5-19	14	9.5	22	15.7	25	19.1	25	14.4	32	47.1
20-39	17	11.6	28	20.0	27	20.6	39	22.4	21	30.9
40-60	12	8.2	18	12.9	13	9.9	13	7.5	5	7.4
Total	147		140		131		174		68	

Note: The collective total represented by these areas does not include all burials; some burials were recovered by local collectors and are of unknown spatial location.

Chi-square values obtained from statistical comparison of these age distributions are listed in Table 14.

TABLE 14

CHI-SQUARE VALUES, DEGREES OF FREEDOM, AND THE PROBABILITY OF OCCURRENCE OBTAINED FROM COMPARISON OF AGE DISTRIBUTIONS IN DIFFERENT BURIAL LOCATIONS

Comparison	Chi-Square Value	Degrees of Freedom	Probability
Area I-Area II	11.32	3	0.025-0.01
Area I-Area III	13.03	3	>0.005
Area I-Area IV	9.83	3	0.025-0.01
Area I-Area V	68.01	3	>0.005
Area II-Area III	0.98	3	0.995-0.975
Area II-Area IV	2.85	3	0.5-0.1
Area II-Area V	36.53	3	>0.005
Area III-Area IV	2.06	3	0.9-0.5
Area III-Area V	29.43	3	>0.005
Area IV-Area V	42.22	3	>0.005

The chi-square statistics demonstrate a similarity of the age distributions of Areas II, III, and IV. Area I (the portion of the cemetery lowest on the hill) and Area V (the village) significantly differ (in all cases >0.05) from one another and from the other burial areas. Examination of the percentage distribution of deaths (see Table 13) illustrates these distinctive features: Area V has a noticeable deficiency of young infants and children; Area I has an excess. Again, for ages 5-19 a dualistic opposition is seen between Area I, the least, and Area V, the most. The majority of individuals recovered from the village were assigned this age category; Area V has twice the number of adolescents, aged 10-14, than any other cemetery area (not shown in table). The final major distinction is the number of deaths involving adults, aged 20-39 years; Area I has the lowest percentage represented, Area V the maximum. Although the age distributions of Areas I and V statistically differ, the relationship appears complementary. If one is not the extreme, the other is.

Demographic data support the hypothesis that the Larson population was infected by smallpox. Areas II, III, and IV exhibit consistency in their age distributions and are believed to represent the "normal" mortality experiences of the Larson people. Individuals recovered from the village (Area V) and probably a few people buried in Area I are smallpox victims. Area V's increase in the frequency of deaths in the age category 5-19, and especially age 10-14, is highly unusual unless explained by an epidemic. Generally this age represents the healthiest segment of the population. The deficiency of infants and young children in the village seems counterbalanced by the excess number in Area I. Earliest deaths in the village may have included the

more vulnerable young which were hastily buried in Area I. A slight tendency for young children to have a higher percentage of deaths occurring more quickly after becoming infected than other age categories has been observed in recent populations (Sommer and Foster 1974). Whether this applies to the Arikara is unknown, but possible.

Normally, burials dating to the final years of village occupation were placed highest up the slope, a location farthest from the village. When the epidemic began, the increase in the mortality rate, confusion, and frustration necessitated rapid disposal of bodies. Burials were placed closer to the village in an area of easier accessibility--Area I.

Historical documentation demonstrates that indigenous populations were exceedingly susceptible to smallpox; the attack rate was high for all ages. "All the Rees (Arikara) and Mandans, Men's Women's and Children, have had the disease . . ." (Abel 1932:138). Likewise, case fatality rates were extremely high for all ages.

> With those who remained about the fort remedies were tried but in few if any cases did success follow. They were bled and died, purged and died. Every kind of care was taken of some old and tried friends. Still nothing but death was the result. A solitary instance here and there of a healthy woman or child who had a mild attack, recovered without assistance. Before all were prostrated the Indians tried their own remedies, but none appeared to be in the least beneficial (Denig 1961:72).

Finally, as the infected number and fatalities rapidly increased, villagers abandoned their homes and the sick and dying in an attempt to escape the disease.

Areas I and V are distinguishable from the other cemetery areas in both the age distributions present and the archaeological history. Area I probably includes many of the early deaths due to smallpox,

especially young children. Area I is likely to also encompass burials predating the epidemic. Grave associations contain relatively few European trade objects. This observation reflects either the presence of early burials or abandonment of traditional graveside activities due to the epidemic.

The possibility that Areas II, III, and IV predate the epidemic allows reconstructing the "normal" underlying vital statistics of the Larson population. A life table using the age distribution of these three areas is presented in Table 15. Comparison of the values of this table to the life table prepared with the total sample allows assessment of the degree of distortion introduced by the inclusion of smallpox victims. (Epidemic-induced burials reflect a change in the mortality rates through time, a situation contrary to the assumptions required for life table construction.)

TABLE 15

ABRIDGED LIFE TABLE CALCULATED USING THE AGE DISTRIBUTIONS OF AREAS II, III, AND IV

x	Dx	dx	lx	qx	Lx	Tx	e^0x
0-1	170	38.20	100.00	.382	69.44	1424.84	14.25
1-4	65	14.61	61.80	.236	238.45	1355.40	21.93
5-9	33	7.42	47.19	.157	217.40	1116.95	23.67
10-14	11	2.47	39.77	.062	192.68	899.55	22.62
15-19	28	6.29	37.30	.169	170.78	706.87	18.95
20-24	17	3.82	31.01	.123	145.50	536.09	17.29
25-29	18	4.04	27.19	.149	125.85	390.59	14.37
30-34	27	6.07	23.15	.262	100.58	264.74	11.44
35-39	32	7.19	17.08	.421	67.43	164.16	9.61
40-44	11	2.47	9.89	.250	43.28	96.73	9.78
45-49	13	2.92	7.42	.394	29.80	53.45	7.20
50-54	9	2.02	4.50	.449	17.45	23.65	5.26
55-59	11	2.47	2.48	.996	6.20	6.20	2.50

In general, the patterning of all life table functions is not drastically altered. Life expectancy values obtained from these two samples are illustrated in Figure 11. A lower life expectancy at all ages is achieved when using the total sample. Exclusion of epidemic victims raises life expectancy, though essentially the same pattern remains. The maximum alteration in subadult life expectancy values was about 1¼ years. The direction of the change, a decrease in life expectancy of the total sample, suggests that an increase in mortality rates was caused by the epidemic.

Calculation of the new crude death rate decreases this figure from 73 to 70. This is another illustration that smallpox increased the crude death rate.

Discrepancy is caused by the inclusion of epidemic-produced mortality. However, the quantitative changes observed in this case study are not dramatic nor prohibitive. Large cemetery samples mask the appearance of brief fluctuations in mortality rates. The data also indicate that if all smallpox victims are excluded by the procedures outlined, times were harsh for the Arikara even preceding the epidemic. Other complications and diseases had a heavy impact on the population prior to the epidemic of 1780-1781.

VIII. VILLAGE POPULATION SIZE

Reconstruction of the Larson village population size is by synthesis of two different approaches, one emphasizing archaeological data, the other biological. Each, when considered separately, has limitations in the form of variables which are not satisfactorily controlled. By pooling the evidence of both, however, estimation of

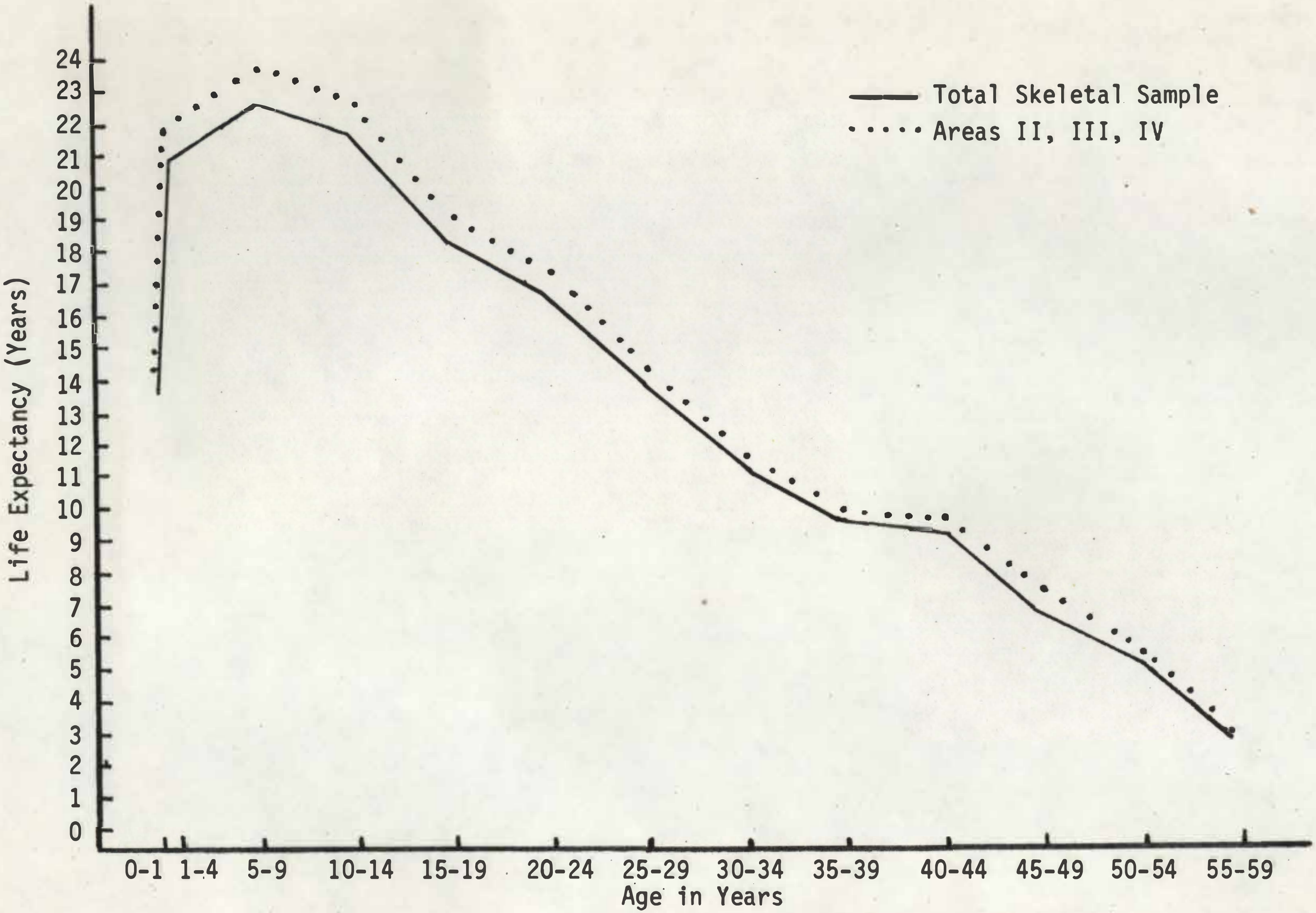

Figure 11. Life expectancy values calculated from the total skeletal collection and from the skeletal sample of Areas II, III, and IV.

population size becomes a more practical endeavor and population size can be more accurately defined. Evidence presented previously indicates that the number of villagers was not constant, but instead decreased during the 30 years of village residence. The objective of the following analysis is to establish an average population size for the time span represented.

The first methodology requires knowledge of two variables: (1) the total number of earth lodges simultaneously occupied in the Larson village, and (2) the number of residents per lodge. The procedure for estimating population size involves multiplying the number of structures by the average number of occupants.

Ethnohistorical sources provide the necessary information concerning an average number of lodge inhabitants. Reportedly, several families lived together (Nasitir 1952:300). Tabeau (Abel 1939:52), an early trader to the Missouri Valley, records that he shared a lodge with four other families. Holder (1970:85) believes an average of 15 individuals per lodge to be a reasonable estimate.

Determination of the exact number of lodges in the Larson village presents more of a problem. According to archaeological data, 29 earth lodges are identifiable within the boundaries of the fortification system (Lyon 1970; Smithsonian Institution n.d.a). Additional lodges probably were located outside of this perimeter (Lehmer in Rucker n.d.), although the exact number is unknown. Arikara villages of the 18th century generally averaged 35 lodges (Lehmer 1971:141). Larson may closely approximate this number; however, to be a little less conservative, an upper limit of 40 was included in the calculations. This upper number is only a rough estimate. A minimum of

29 lodges is well documented and should help establish a lower limit for population size.

To test validity of this estimating procedure, it was applied to the later Leavenworth site. Leavenworth was composed of two adjoining villages which, according to historical sources, contained 70 and 71 lodges (Chittenden 1935:614). Approximately 2000 people resided at Leavenworth (Bass, Evans, and Jantz 1971:161). Multiplication of 141, the total number of earth lodges, by an average of 15 occupants per lodge gives a population estimate of 2100 people. Definitely, results of this test are favorable and justify application to the Larson problem.

Table 16 gives population sizes estimated for the Larson site using the procedures outlined. The minimum number is 435; the theoretical maximum is 600.

TABLE 16

LARSON POPULATION SIZE ESTIMATED BY THE NUMBER OF EARTH LODGES IN THE VILLAGE

Number of Lodges	Average Number of Occupants	Population Size
29	15	435
35	15	525
40	15	600

Population size can be determined from biological data with the knowledge of three variables: (1) the population crude mortality rate, (2) the total number of individuals buried, and (3) the number of years represented by the skeletal deposits. The following formula allows reconstruction (see Ubelaker 1974:66):

$$P = \frac{1000\ N}{mT}$$

P = population size
N = total number of individuals buried
T = time interval represented by skeletal sample
m = crude death rate

The total number of individuals recovered from the cemetery and village is 706. Some skeletal material was lost due to salvage conditions, about 10 percent. Application of a 10-percent correction factor raises the total collection number to 777. Calculations were made with this estimate and also, to be cautious, with a correction factor assuming 15 percent of the total number to be unrecovered (recorrected number equals 812). It is doubtful that the missing number involves this high a percentage, though not impossible.

The crude mortality rate for the skeletal sample was determined from the life table as previously discussed. A crude death rate of 70, the pre-epidemic normal mortality rate, was used for calculations.

The final variable, the time factor, has been mentioned in previous chapters. Due to seasonal shifts in Arikara settlement patterns, the actual length of village occupation was not 31 years, but less. In winter the Arikara moved to more protected areas in the river bottoms. During certain seasons, extended hunting expeditions were

undertaken by the majority of villagers. Those remaining behind in the hunting seasons were the old and sick who perhaps, due to their health and age, were actually the ones most likely to die. Nevertheless, the remaining segment of the population was a minority, a circumstance requiring a reduced time factor.

Table 17 gives estimates of Larson population size using the variables and procedures discussed. If the Arikara lived throughout the year in the village, population size was between 358 and 374 people. According to the minimum size determined by the number of earth lodges (435), this is an underestimate. Only by allowing for village abandonment during two months per year is this minimum attained. The estimate of population size accounting for village abandonment for an average of four months per annum seems realistic (size = 536-560 people). Since additional lodges were outside the fortification perimeter, size calculated by the archaeological approach supports this higher estimate. Calculations based on the Arikara being absent six months per year are, as predicted, much too high.

The biological and archaeological approaches of estimating population size indicate that a more realistic estimate is achieved by modifying the time factor. Population size of the Larson village is estimated to have been between 430 and 560 people. Perhaps, due to the population decrease through time, both upper and lower limits were actually observed.

TABLE 17

CALCULATION OF POPULATION SIZE USING TWO ESTIMATES FOR NUMBER DEAD AND VARIOUS TIME INTERVALS

Total No. of Dead	Crude Death Rate	Time Interval (Years)		Population Size
777	70	Year-round residence	31.0	358
777	70	Absent 2 months/year	25.8	430
777	70	Absent 4 months/year	20.7	536
777	70	Absent 6 months/year	15.5	716
812	70		31.0	374
812	70		25.8	450
812	70		20.7	560
812	70		15.5	748

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