African Population, 1650-1950:
The Eras of Enslavement and Colonial Rule

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Draft Manuscript
September 2014

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Preface

Comparative studies on historical population worldwide are gaining renewed attention. A small 2013 conference at the International Institute of Social History in Amsterdam featured presentations with new data on China, Russia, Latin America, Africa, and medieval Europe. This work was initially hoped to provide the basis for updating the 1978 summary of world population by McEvedy and Jones. In practice, participants had to distinguish regions where there are solidly established population estimates from those where so such solid estimates have been developed. While the conference showed that preparation of a full set of regional estimates will take some time, it also showed how new techniques and resources are making it possible to achieve substantial advances in estimating populations in time and space. Part of the reason for the increased attention to population history on a global scale is the recognition that, in order to comprehend the unfolding of society at a global level, and in order to make plans for facing the global future, we need solid historical estimates of population and migration for every region.

Africa, a major world region, has had relatively dense population by comparison with other regions, but the documentation of that population has been scarce. Africa's weakness in global affairs has led to a situation in which, despite the large and rapidly growing population of the continent, little attention has been given to developing data on its present and especially on its past. Nonetheless, study of Africa's population has been taking place over the years, and it is now possible to present this comprehensive analysis. The analysis should permit a great expansion of comparative analysis, in that our population estimates now make it possible to compare population density and especially per-capita figures (for trade, production, etc.) for African and overseas regions.

Our results argue for an African continental population that fluctuated at roughly 150 million inhabitants from 1650 through 1900, in contrast to the more commonly cited totals of from half to two-thirds that amount. Our linkage of analyses—across different regions of the African continent and across the full range of time from 1650 to the present—brought new insights and the correction of important errors in earlier scholarship. For over 60 regions within the continent, we have estimated decennial populations from 1650 to 1950, accounting for variations in the intensity of enslavement up to 1890 and variations in a wider range of factors thereafter. In some ways this study is still at the level of a broad hypothesis on African population, rather than verified figures for past populations, but we hope that our work provides an organized basis on which further studies can usefully build.

This study has been slow in developing, but it has been able to take advantage of improvements in technology and analysis. A key turn in development of the analysis was linking known population figures for the period after 1950 with speculative estimates for the colonial and precolonial eras. This link, emphasized in an important personal communication by Bruce Fetter, led to the inclusion of colonial and postcolonial analyses in what had previously been a precolonial study. The new perspective was implemented especially through the work of Scott Nickleach, who joined the project in 2007 as a graduate researcher, but brought with it a systematic statistical analysis, especially the addition of Monte Carlo estimates of variation in data. In a sense these are not highly advanced statistical techniques, but they were new to the

work of estimating historical population figures. As the collaboration continued, Nickleach became a full author and led in expanding statements on error margins, in the crude-rate estimates of population from 1950 to 1850, and in the backwards-and-forwards estimates of population for the nineteenth century.

We wish to acknowledge those who have assisted us on this long path. William S. Griffiths led in developing the initial Pascal-language simulation of African population change. The John Simon Guggenheim Foundation provided support for a year's work by Manning at the Population Studies Center at the University of Pennsylvania, where Samuel Preston, the late Etienne van de Walle, Jane Menken, and Tukufu Zuberi provided important consultation. Alex Mechnikov and __ prepared the online version of the simulation model, which remained available from 2001 to 2006. Kiron Skinner and Stephen Fienberg at Carnegie Mellon University provided essential encouragement for our work. CMU statistics grad students Di Liu and James Sharpnack completed the initial statistical survey of Atlantic slave-trade data. Yun Zhang of the University of Pittsburgh revised and completed the Bayesian estimates of Atlantic slave trade. Brian McGill, Jr., and Bowen Yi completed the revisions and current output of the overall population simulation.

This preliminary version of our manuscript presents our first full assembly of our data and arguments. Our plan is to circulate it to those knowledgeable on the subject if African population and migration, ask for comments and corrections, and expect to submit a revised version of the manuscript to a publisher in 2015.

Patrick Manning

Scott Nickleach

Chapter 1

Overview: The Problem of African Population

Statement of the Problem
Outlines of African population history
Enslavement and population decline: an heuristic introduction
Framework and Methods
Organization of the Analysis
Conclusion: History Backwards and Forwards

Statement of the Problem

The population of Africa is known to have increased very rapidly in the late twentieth century: the continental population grew by an average 26.6 per thousand per year (or 2.66 % per year) from 1950 to 2000. For the period before 1950, in contrast, the documentation of African population is uncertain and for times before 1900 the data are scattered at best. Yet this book proposes and implements methods for assembling data to generate solid estimates of African population over time. We argue that African population grew rather slowly in the first half of the twentieth century (at an average growth rate of 8 per thousand per year or 0.8% per year), and that in the two or three previous centuries it grew almost not at all because of the high rates of mortality that Africa shared with other tropical regions and the additional negative effects of slave trade, which carried off millions of people and increased the mortality of those who remained in sub-Saharan Africa. The causes of recent population acceleration include improved health conditions resulting from the combination of relative social peace, public health measures, immunological changes, and new economic opportunities. These two sharply contrasting periods in African population history—with the sharpest inflection between them in the 1940s—can be better understood when they are studied together.

This chapter identifies the major issues in African population size and structure over the past four centuries, especially as these have involved slave trades—the enslavement of captives destined to be settled both beyond sub-Saharan Africa and within the continent. The chapter summarizes the main historical arguments of the book, including the relatively high population of the continent throughout the past four centuries, the slow growth of African population to 1940, and the negative impact of slave trade. It introduces the multiple methods of analysis, with attention to statistical analysis, and lays out the steps of the analysis, chapter by chapter. The section entitled "Enslavement and Population Decline" illustrates one major difference between our analysis and previous approaches: we focus on the age and sex composition of the population and describe how distorting the age and sex ratios of a population by migration or mortality can have a major impact on the population's natural pattern of evolution. A concluding section entitled “History Backwards and Forwards” lays out the logic of reconstructing history through a mixture of primary documents, logical analysis of social science variables, and close attention to

ensuring that empirical and interpretive statements for each time period are consistent with those for other times. At the same time, we emphasize the problems of *segmentation* in demographic and other study, in which studies of Africa have been cut off from studies of the rest of the world, and studies of regions and time periods for Africa have been cut off from each other. Studies of African migration, a substantial part of migration studies for the past 40 years, have only recently become connected with other parts of the migration literature.[1]

This book reconsiders and expands the earlier analysis of African population and slavery by one of the authors.(Manning, 1990) In that earlier work, the basic question was: "How did the size and structure of African population change in response to the overseas and trans-Saharan slave trade of the eighteenth and nineteenth centuries?" The answer proposed was that export slave trade brought three principal results: decline in the population of West and Central Africa during the eighteenth and nineteenth centuries; decline in the population of East Africa during the nineteenth century; and distortion of adult sex ratios in many parts of Africa. Put more globally, it was argued that, as a result of the external slave trade, total African population in the eighteenth and nineteenth century remained stagnant at a time when other regions were growing in population. These hypotheses were shown to be plausible but they could not be documented with sufficient thoroughness to enable a detailed debate on their validity.[2]

In this book we return to the issue with a collaborative team: a historian (Manning) and a statistician (Nickleach). We find that, in order to develop a coherent answer to the original question, we need to broaden fundamentally the objectives and deepen the analysis. First, we are analyzing over a longer time period—from the seventeenth through the twentieth centuries, including the eras of enslavement, European colonial rule, and national independence—in order to test more fully for consistency among various parts of the analysis of population. Second, we deepen the statistical analysis, estimating error margins for all the population sizes and migratory flows that we calculate. Third, we explore in depth the changing patterns of tropical demography, especially the relatively high death rates of Africa. Fourth, we account for global socio-economic forces. The external demand for slave labor was one such force, but here we address such others as global demand for agricultural commodities and changing racial categorization. Fifth, we assess, more systematically than before, the process of enslavement within sub-Saharan Africa: its timing, its magnitude, and its links to other processes. In each dimension of our methodology, we seek to provide a full and transparent presentation of our evidence, methods, and results, which rely on a long-term, global framework and on demographic and statistical methods. The results of this study reaffirm in general the hypotheses of the earlier study—declining populations and distorted sex ratios in populations affected by slave trade—but offer much more detail on the size and composition of African populations and set the slave trade more firmly in the context of other factors affecting African population.

This is migration history, so we work systematically to distinguish migrants from those who remain settled. In one sense migrants are additions to or subtractions from settled populations; in other senses migrants are members of settled groups who carry out the act of migration for brief portions of their life before returning home, or they are currently settled

[1] For an overview of migration history and the theoretical literature in migration, see Manning and Trimmer 2012.
[2] Reviews of the 1990 book treated the demographic hypotheses as plausible but unverified; there were no responses that engaged the details of the demographic argument.

people who are identified by previous acts of migration, or they are people whose lives center around successive migrations. Since many of the migrants under study in this work were in slave status, we draw immediate attention to the terminology we use, distinguishing "captives" from "slaves." That is, "captives" were the migrants—those recently seized and in process of movement from the point of their seizure to their destination. "Slaves" were those persons held in subjugation but who had been settled into a relatively permanent status. As we will show, the identifies, conditions, time frames, and especially the fertility and mortality of captives were quite different from those of slaves, and the transition from status of captive to that of slave was nearly as significant as the preceding transition of enslavement and the hoped-for transition of liberation.

Outlines of African population history

African population experienced disruption especially because of the high levels of enslavement from the seventeenth through the nineteenth centuries. Reverberations of that era of enslavement continued to shape African population through the twentieth century. Four points sum up much of the argument that we have developed:

1. African population has been much larger than is usually estimated, both in recent and earlier times. As a corollary to this point, it is argued that African populations before 1950 grew at a slower rate than has previously been assumed.

2. Overseas slave trade is confirmed to have brought population decline and distortion in sex ratios for much of West and Central Africa in the eighteenth and nineteenth centuries and for much of East and Northeast Africa in the nineteenth century.

3. In the nineteenth century, both the rate of enslavement and the rate of retention within Africa of those enslaved are demonstrated to have increased sharply for much of sub-Saharan Africa, so that slave-holding reached a peak in the late nineteenth century. As a corollary to this point, the numbers of enslaved Africans before the nineteenth century were small compared to the nineteenth-century levels.

4. From the late nineteenth to the mid-twentieth century, European colonization of Africa brought additional disruption to African population, through imposition of new frontiers and with programs of recruitment and forced labor within those frontiers.

The details of our interpretation appear throughout the book in four periods: from 1950 to 2000, 1890 to 1950, 1790 to 1890, and 1650 to 1790. The periods differ from one another in their dynamics of population change and the nature of the evidence with which they are documented. Because evidence is more plentiful and more secure for recent times, we will describe African population working from the most recent period to the earlier periods.

1950 – 2000. Population of the African continent rose from 220 million in 1950 to over 800 million in 2000. This population explosion accompanied the era of decolonization and the

formation of African nations. Population growth rates exceeded 25 per thousand per year (2.5% per year) for that entire period, in an extraordinary affirmation of the value of life. Nor was the African population explosion an isolated experience, in that populations grew at similar rates all over the world, and especially in the tropical and subtropical world, The rapid growth in population resulted from persistently high fertility accompanied by declining mortality. Declining mortality resulted from improvements in public health and in medical treatment, but also from changes in productive technology, economic organization, and social organization that made it possible for the same land to support many more people.

1890 – 1950. Population rose in this era from 140 million in 1890 to 170 million in 1930 and to 220 million in 1950. The average annual growth rate in this era was 7.5 per thousand per year (0.75% per year). This modest growth rate shows that the high annual population growth rates of the late twentieth century cannot therefore be attributed to these earlier times. The 1940s were a decade of accelerating population growth rate, but before 1940 virtually no African population grew at as much as 10 per thousand per year (1% per year). At the beginning of the twentieth century, rates of population growth were more commonly 2 per thousand per year (0.2% per year).

The era of full-scale European colonization of Africa began just before 1900. Colonization brought new opportunities as well as new forms of oppression. When the invading Europeans seized power, many of the Africans held in bondage took the opportunity to escape their masters and become free (or at least ex-slaves). Perhaps as many as half of those in slavery left their owners in this situation. Others—especially women who wished to remain with their children—remained with their masters, and sought to negotiate an improvement in their status. Fertility remained little changed but mortality declined. For the towns that Europeans chose as their capitals, many ex-slaves joined the population and the workforce, and contributed to urban growth. The net result of these changes brought by colonial rule, along with declines in mortality rates that were felt all over the world in the early twentieth century, brought a rise in the continental population of Africa.

A dramatic but underemphasized social change of this era was the expansion of African peasantries. African peasants consisted of free, rural families—mostly working in agriculture but also working with domestic animals, in fishing, and as artisans. In some cases peasants owned their own lands; in other cases they paid rents or shared their produce with landowners. African peasants of the nineteenth and twentieth centuries are best known as producers of food crops (for home consumption and for local markets) and for production of export crops (palm oil and kernels, peanuts, cocoa, coffee, sisal, maize, and others). The expansion of African peasantries came especially because of the gradual liberation of millions of slaves. In a transition somewhat parallel to the emancipation of slaves in the Americas, former slaves left the forced yet market-oriented production of commodities for the masters, and entered voluntary production of goods, some for home consumption and some for markets of their choosing. In addition, since ex-slaves were able to form and nurture their own families, their populations grew at a higher rate.

From 1930, the acceleration in African population growth continued. Among the factors thought to be important during the 1940s was widespread spraying of the newly developed pesticide DDT, which was effective in repressing the mosquitoes that carried malaria. Malaria, while gradually reduced in its influence, continued to ravage African populations, bringing a

high mortality to African children, and bringing frequent illness and occasional death to adults. DDT and other pesticides, while bringing an impressive short-term reduction in malaria, compounded problems in the longer run because the mosquitoes developed immune strains and the DDT, in addition to killing targeted mosquitoes, killed a great deal more in animal and even plant life.[3]

1790 – 1890. Aggregate African population remained virtually unchanged at some 140 million in this era. Nevertheless, this steady total encompassed a complex set of contradictory demographic changes. Transatlantic slave trade remained at a relatively high level until 1840, then fell to a very low level after 1850—conveying a total of over two million captives across the Atlantic during the nineteenth century. Meanwhile the volume of export slave trade across the Sahara, the Red Sea, and the Indian Ocean rose to a new high in the early nineteenth century and declined only late in the century, totaling another two million captives exported from sub-Saharan Africa during that period. In the same era, paradoxically, enslavement and purchase of captives in many regions of the African continent rose to unprecedented levels. As a result, African regional populations were able to grow in some regions where external slave trade declined, but in other regions the population declined because of the corrosive effects of slave trade to African destinations. Yet another response was a relative growth in North African population because of the arrival of new captives from south of the Sahara. The net result for the continent was a modest change in total population which we have estimated as from 151 million in 1790 to 149 million in 1890.

1650 – 1790. African continental population grew from just over 141 million in 1650 to 148 million in 1700, and remained virtually unchanged at 149 million in 1790. The earliest stages of the Atlantic slave trade began in roughly 1450. By 1650, the transport of African captives across the Atlantic exceeded the volume of the trans-Saharan slave trade. The Atlantic trade continued its uninterrupted increase to 1790. Beginning in the late seventeenth century, the slave trade began to cause population decline in certain regions of the western coast of Africa: coastal Angola, the Bight of Benin, and perhaps Upper Guinea. By the early eighteenth century, this population drain had become large enough to decrease the population of coastal West Africa and Central Africa in general—such decline offset any growth in other parts of the continent.

The Atlantic slave trade, from 1650 to 1790, brought the dispatch across the Atlantic of nearly eight million persons from the western and even eastern shores of Africa. In the same period, nearly two million persons were transported in captivity across the Sahara, the Red Sea, and the Indian Ocean. In this era, especially from 1730 to 1850, the population of West Africa and West Central Africa declined because of the losses brought by enslavement, while populations of other areas of the continent were able to grow. Also in this period, the population of North Africa grew at the expense of the savanna regions of the sub-Saharan fringe, also as a result of slave trade. Further, the rapid expansion of demand for captives within Africa fueled ongoing warfare, enslavement, displacement, and the accompanying mortality.

Before 1650. We estimate that African population grew from perhaps 100 million in 1450 to 130 million in 1650. Over the long run, according to the analysis in the pages to follow, the population of the African continent grew at no more than 1 per thousand per year (0.1% per

[3] Webb on colonial-era anti-malarial programs.

year) from 1450, when Portuguese vessels began sailing along the sub-Saharan coast of Africa, until 1650. By 1650, the African continent had a population of some 130 million. (On average, Africa was then about half as densely populated as Europe. That is, Europe west of the Urals had 100 million people spread across 10 million square kilometers, while Africa had 140 million people spread across 30 million square kilometers, including the nearly empty 5 million square kilometers of the Sahara.)[4] During these two centuries, over half a million Africans were carried off in captivity from the western shores of the continent, to be settled on the Atlantic islands, in Iberia, and, increasingly, in the Americas. In the same two centuries, roughly a million people were transported from Subsaharan Africa across the Sahara, the Red Sea, and the Indian Ocean, to live out their lives as slaves in the Mediterranean, the Arabian Peninsula, the Persian Gulf, in India, and on islands of the Indian Ocean.

Over the full period from 1650 to 2000, the population of Africa grew at an average pace similar to but slightly slower than that of Europe. Yet when viewed in briefer slices of time, the differences are seen to have been immense. From the seventeenth to the end of the nineteenth century, African populations remained roughly stationary, while European populations grew throughout the period and accelerated as the period wore on. For the twentieth century, rates of European population growth declined sharply, while African growth rates grew even more sharply. Population changes for Asia and the Americas followed still different patterns. These are the conclusions we will advance and document in the chapters below.

Enslavement and Population Decline: an heuristic introduction

The external trade in African captives, reinforced by the capture and retention of people in slavery within Africa, caused decline in African population, especially in the eighteenth and nineteenth centuries. This argument, documented throughout the book, is here presented in heuristic form, so that the reader can anticipate the type of argument that will be made.

The distinguished African historian John D. Fage proposed, in 1969, a common-sense interpretation of the Atlantic slave trade. Since it seemed that the proportion of West and Central Africans sent overseas in captivity averaged only two per thousand (0.2% per year), African population would not be reduced as long as the birth rate exceeded the same rate of 2 per thousand per year. Indeed, since captives sent across the Atlantic included almost twice as many males as females, Fage concluded confidently that African population was not reduced by slave trade, and many other scholars joined him in this opinion.

African forced migration, especially from 1650 to 1850, was the greatest overseas migration up to that time: over ten million captive migrants crossed the Atlantic within two centuries. Yet in a shorter period (from 1840 to 1940), far greater numbers of migrants left Europe, India, and China—roughly 50, 30, and 50 million migrants each, for a total of 130 million migrants—without reducing their home population (McKeown 2004). How could it be that a smaller migration over a longer time caused decline in African population? Details of the argument are developed throughout the book. Here, the main principle is introduced through a simplified, heuristic example. It demonstrates that what mattered, in determining whether

[4] Similarly, Africa as a whole was about half as densely populated as Eurasia as a whole. For further such comparisons between Africa and Eurasia, see Manning 2014.

African populations would grow or decline, was the proportion of females of childbearing age lost through capture or mortality.

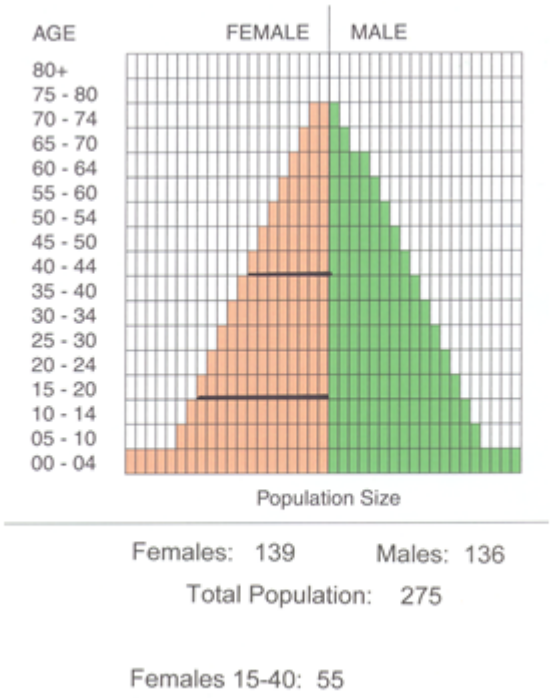


Figure 1.1. Hypothetical African population, by age and sex.

The pyramid in Figure 1.1 shows a hypothetical African population of 139 females and 136 males. It includes 55 females of ages 15-40, most of them fertile. It is assumed that the population is just reproducing itself each year. That is, the 55 females of ages 15-40 give birth to 20 surviving female and 18 surviving male infants—just enough to offset deaths at older ages. To this situation of population stasis, we add the effect of enslavement: it is assumed that 3 females and 6 males are lost to the population in the course of three successive five-year periods (as shown in the three pyramids in Figure 1.2). Since those who were taken in captivity remain gone, these losses are cumulative. In the third period the total population has declined by 27 persons or 10%, while the fertile female population has declined by 9 persons or 16%, as the average 1.1% loss per year is compounded. Because of the elevated death rate among youth, the number of female births would have to rise by 5 in each 5-year period in order to yield an additional 3 fertile women who could offset the losses. Since males and females are born in almost equal numbers, to compensate for the loss of three adult females each five years, total births would have to rise by ten (5 males and 5 females) in each five-year period. This would also require the birth of another 5 males in each 5-year period, so that the inherent growth rate would be 10/275 or 36 per thousand in 5 years, or over 7 per thousand per year. So to prevent long-term decline in the population, the loss (to enslavement) of 9 adult females each 5 years would require a population growing at the rate of 20 persons in each 5 years—that is, by nearly 1.5% per year.[5]

[5] Details of this calculation.

Losses to Enslavement: Total Population and Fertile Females

	Years 1-5		Years 6-10		Years 11-15	
	Initial Pop.	Captives	Initial Pop.	Captives	Initial Pop.	Captives
Females	139	3 (2.2%)	136	3 (2.2%)	133	3 (2.3%)
Males	136	6 (4.4%)	130	6 (4.6%)	124	6 (4.8%)
Total	275	9 (3.3%)	266	9 (3.4%)	257	9 (3.5%)
Females 15-40	55	3 (5.5%)	52	3 (5.8%)	49	3 (6.1%)
Cumulative loss	55	3 (5.5%)		6 (10.9%)		9 (16.4%)

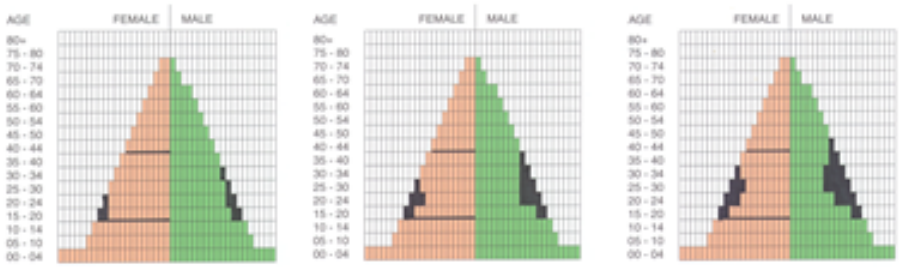


Fig. 1.2. Enslavement loss in successive 5-year periods.

This exercise demonstrates that—under African conditions of high overall mortality—the steady death or capture of a small number of people, even if most of them are male, can result in long-term decline of a population, especially if the number of females taken is more than 2% of the fertile female population. We will return to this basic lesson throughout the book, and show how it demonstrates that Africa in the seventeenth and eighteenth century had 140 to 150 million inhabitants, a total roughly equal to that of contemporary Europe.

Framework and Organization of the Analysis

The overall task of this study is to estimate the size and structure of African population over space and time, based on the full range of available data and available information on relationships among data. The analysis includes comparisons of African populations with those of other regions and gives particular attention to information on forced migratory movements of Africans; in this light, it includes analysis of population of sub-Saharan African descent in the Americas, North Africa, and Eurasia. To conduct this analysis, we have drawn on a wide variety of data; in addition we have estimated and projected data that were not given in the documentary record. To clarify and analyze this evidence we have had to develop a broad and inclusive analytical framework, a number of specific methods, a systematic linkage of the methods, and a review to ensure the consistency of our work.

This is empirical work, in the sense that the purpose is to come up with specific descriptions of historical population. But there are spaces in the documentary evidence, so we

need to make estimates to fill in the gaps. It is our intention to base our estimates on known patterns and data drawn from various fields, rather than on sheer speculation. We do not accept a dichotomy between "fact" and "theory," but see the two as overlapping and mutually supportive. We find that we have been drawn into the discussion that ranges across several fields of analysis, in which analysts are attempting to conceptualize the distinctions and overlaps of data, estimates, information, and knowledge, and attempting to clarify the interplay of evidence and the theories which generate the evidence.[6]

The academic field of our analysis is demographic history.[7] Within that field, ours is a study both in population history and in migration history. Two major changes within demographic studies in recent decades have enhanced the potential depth of this study. First, at a technical level, developments in spreadsheets and other computer methods have made is possible to calculate with ease the demographic variables and relationships which earlier were known in principle but could be explored only with slow and laborious analysis. Second, at a conceptual level, and partly for the same reason, demographic analysis has extended its interest beyond fertility and mortality to include migration.[8]

As a result, it is now easier to extend formal demographic analysis to migration studies, a type of analysis that long remained separate from demography. Within the disciplines of sociology, economics, and anthropology, analysts traced flows of migrants and attempted to explain reasons for departure, processes of settlement, and (less often) the experience of migration. (Thomas 1954, Massey 1999, Massey et al. 1993, Portes and Borocz 1989) Historians, exploring migrations that were in many ways similar, tended to focus on constructing narratives of the migratory flow.[9] These social scientists downplayed the attention to age and sex composition characterizing demographic analysis; demographers in turn were reluctant to take on the extra complications and erratic patterns of migration. The strength of migration studies, however, has been the attention to factors beyond the strictly demographic which have influenced migration. These include prices, climate, food supply, work, disease, war, and the activities of states. Recently there has been more exchange among disciplines, and more comparison of migrations across time. As a result, both the technical and analytical conditions are now in place for studies of population and migration addressing a wide range of variables: population size, number of migrants, settlers and their descendants, rates of birth, death, and migration, plus the wider range of variables explored in migration studies.(Lucassen et al. 2010; Manning and Trimmer 2012, Hoerder 2002)

At one level, our analysis focuses on specificity. We rely on formal modeling to trace the reproduction of populations, to define patterns of migration, and to trace the impact of migration on populations at the points of origin and destination. Such models require precise statements of the relations among variables. The benefits of such attention to precision are occasionally striking, as the results of a particular relationship are traced throughout the system of demographic and social relations. For instance, the specific sex ratios of the Atlantic slave trade can be shown to have brought substantial differences between African and New World

[6] Works addressing overlap of theory, simulation, and empirical work.
[7] Or we could label the work somewhat more ambitiously as historical demography—the latter would indicate a somewhat more rigorous analysis than for former.
[8] citations on demographic analysis extending to migration.
[9] Historical analyses: Atlantic migration, African slave trade.

populations of African descent. Since most captives taken across the Atlantic were male, the New World societies were systematically short of adult females; since most of those carried away from western Africa were male, African societies were systematically short of adult males. African societies and those of the New World were different for many reasons, but this demographic distinction served to expand those differences in ways that have yet to be fully explored.(Manning 1981; Manning 1990a; Geggus 1989)

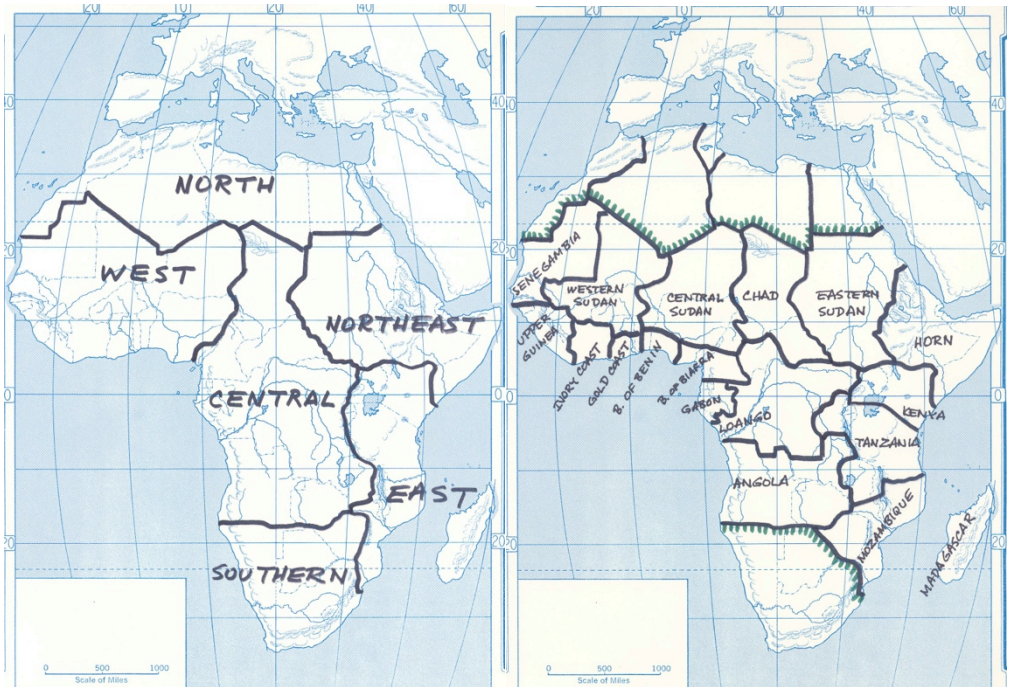
Because we are dealing with a rather large number of variables, we must identify and define them with care. Here we make some main distinctions in demographic variables. To begin with, we assess *stocks* of population as of a given moment, *flows* of migrants from one status to another within a given time period, and *rates of change* of each of these categories within a given time period. Further, each category can be described by its *composition*, broken down by age, sex, ethnicity, free or slave status, etc. The *stocks* of population are the total numbers of persons within a population at a given moment, however that population is defined. The *flows* include movements of individuals from one category to another, where the categories are defined by age, geography, and status. The "migration" from one age to another is dependable, a core aspect of the demographic analysis on which we rely. The migration from one geographic location to another is far less predictable than the advance in age, and we give it detailed attention, especially through study of slave trade. Migration from one status to another, as analyzed here, centers on movement between free and slave status (though the events of birth and death can be seen as status change). Individuals can also move among nationalities, ethnicities, or occupations during their lives, and these shifts in status can be important in the analysis of population. For all of these flows of population, one can in principle explore the composition of the flow, breaking it down by age, sex, and various sorts of status. The *rates of change* in population and in migration are parallel but distinct measures. For instance, a constant flow of migration changes the stock of population, so that even unchanging migration is associated with a rate of change in population. Increase in migration reflects a positive rate of change, and brings a change to the rate of change in population. Thus, we address rates of change that are both first-order and second-order differences. Attention to the *composition* of both population stocks and migratory flows—in terms of age, sex, and the various measures of social status—commonly reveals that superficially similar groups are dramatically different in their makeup and therefore in their behavior.

A further and very important aspect of our specific analysis is our attention to error margins. Especially since we are working over a large space, a long time period, and with scattered primary data, it is important to be able to convey a logical and reliable indication of the precision and dependability of our assumptions and our conclusions. The field of statistics has long since developed principles for calculating the precision and accuracy of quantitative studies. Fortunately, the increased power and flexibility of computers now makes it possible to apply many of these statistical procedures far more widely. In this study, we estimate the error margins in our estimates of stocks of population and flows of migration.[10] Similarly, we calculate the relative importance of the various determinants of population change, at least as we have modeled them.[11] The latter analysis, for instance, shows that the overall level of mortality was the most important determinant of African population change, even in the era of slave trade.

[10] Sources on statistical analysis.
[11] This sensitivity analysis is developed in Chapter 8. [Add more here on statistics.]

At a level beyond that of specificity, our analysis focuses on generality and comprehensiveness. We have taken a global approach to all the main dimensions of the study. While we cannot hope to account for all the specifics of existing information, we can attempt to address all the *types* of information. That is, having once set the external limits of our study, we have sought to address all the spaces, all the times, all the populations, and even all the variables relevant to African population within those limits. This strategy is intended to help us locate and explore the main relationships among different sorts of information.

By vital rates we mean rates of birth, death, and migration. Birth and death rates are the most obvious and vital of vital rates, and the most commonly recorded. But migration is a fundamentally important human process, and our ability to trace migration and its implications has improved greatly with modern spreadsheets. As we see it, future studies of human population will require a special effort to combine all the different ways of analyzing birth, death, and migration. In our work below, we seek to distinguish between strictly *demographic* changes and changes to population that result from factors that we call *environmental* and which include drought, famine, economic prosperity, political oppression and even cultural change.[12]



Map 1.1
Major African Regions

Map 1.2
Regions of Analysis

In terms of space, our analysis addresses the entire African continent and gives some attention to the destinations of African captives in the New World and the Old World. The population estimates are developed for some 70 territorial units of the African continent, plus Madagascar. The territorial units consist of modern nations, the preceding colonial territories, and provinces or groups of provinces within them.[13] For instance, we have broken modern national units into northern and southern regions for Sudan, Mozambique, Ghana, and Benin;

[12] Expand discussion of this notion of "demographic" vs. "environmental" factors.
[13] Asiwaju on the similarities of colonial and precolonial frontiers.

into eastern and western regions for Zambia and Central African Republic; while Nigeria is broken into its colonial regions of North, East, and West. We then aggregate these territorial and sub-territorial estimates into population estimates for geographic regions and slave-trade regions of Africa. Territories of North Africa and South Africa are included in these estimates, though they were not sources of large numbers of slaves, because their inclusion strengthens the basis for continental comparison of population size, composition, and growth rates.

In its temporal dimension, our study focuses most explicitly on the period 1650 – 1950. But it also extends up to the year 2000, because African populations are best known for this recent period. The study also includes some consideration of the period before 1650, to make explicit the alternative interpretations of African population in that early time and their implications for the understanding of population after 1650. Within the bounds of our study, we have relied on several measures of time. We have adopted decennial periods for population figures, as is standard in census-taking. We have analyzed population change in five-year periods of individual lives, as is standard in demographic analysis. And we have divided the period of our central analysis into three periods: 1650-1790, 1790-1890, and 1890-1950—based on a combination of the types of data available and the character of demographic change within each period.

Overall, our task is to link the specific and general aspects of our analysis into a coherent interpretation. For historians, accustomed to working steadily forward through documents in a narrative, this complex framework may seem unfamiliar. Our panoply of methods—the mix of documentary data and estimated "facts," the use of demographic analysis and social science theory, the formal modeling, the explicit definition of multiple variables, the attention to statistical margins of error, the effort to conduct global analysis along several dimensions—adds a great deal to the simple notion of lining up facts to pose an interpretation. We argue that the combination of these approaches is appropriate to maximizing our knowledge of the history of African population.

The first section of the book, "The Problem," begins in this chapter with an introductory overview. It summarizes the overall argument, introduces key terms, and introduces the conceptual underpinning of the analysis. Chapters 2 and 3 review the previous estimates of African population and migration. Chapter 2 reviews the estimates of continental African population proposed from the sixteenth century to the early twenty-first century; it also reviews analyses of slave trade from Africa to New World and Old World destinations, from the 1969 work of Philip Curtin to the online Transatlantic Slave Trade Database directed by David Eltis. Chapter 3 reconsiders the various efforts to combine data on slave trade and on African population in order to estimate the effect of slave trade on African population. The extensive literature of the late twentieth century brought controversy and some progress in estimating the volume and composition of Atlantic slave trade and other external slave trade from Africa. In addition, the early twenty-first century brought a lively expansion in studies of enslavement in eastern Africa and in the Indian Ocean region.

The second section of this book, "Evidence," consists of three chapters developing the evidentiary basis for our revised interpretation, centering on rates of birth, death, and migration for African populations. Chapter 4 addresses African vital rates for the period from 1890 to 2000 in two sections. First, it presents vital rates for the period since 1950 as they have been

summarized by the United Nations Population Office. Second, the chapter presents an analysis of vital rates for the early twentieth century, including comparative growth rates for the tropical world drawn especially from India. These data provide the anchor for backward projections of African population and estimates of twentieth-century growth rates in space and time. Chapter 5 develops estimates of precolonial (pre-twentieth-century) rates of fertility, mortality, and migration for free African populations and for captives, diaspora communities, and the enslaved in Africa. These vital rates provide information on the overall rates of birth, death, and migration in precolonial Africa. Chapter 6, working from a review of the qualitative literature on slavery in precolonial Africa, develops an interpretation of continental migration—the magnitude and direction of enslavement over time for various African regions.

The book's third section, "Methods," includes three chapters setting forth the analytical basis for our revised interpretation. Chapter 7 introduces a set of analytical models of African population change. First we present an overall and general statement of a model for African population change, described in qualitative terms. Then we introduce two main types of models of migration and population change, relying respectively on *crude rates* of demographic change and on or *composition-specific rates* (that is, age- and sex-specific rates) of change. Thereafter we explore the specifics of data on migration, for which the sharp variations in quality lead us to a categorization separating "multi-perspective" approaches to documentation from "voyage-based data." Chapter 8 explores the characteristics of both of the main models—with crude rates and category-specific rates. It presents the strategy of using models and data for projecting population: for the period from 1890 to 1950 (using the crude-rate model) and for the period from 1650 to 1890 (using the composition-specific model). For the composition-specific model of population with enslavement, the chapter shows the sensitivity of calculated populations to the rates of birth, death, and migration used in the calculations.[14] In addition, Chapter 8 documents the error margin of the analysis, both for export slave trade and for continental population change. Chapter 9 applies various models to estimate the migration streams of captives—first for transatlantic slave trade; then for export slave trade across the Sahara, the Red Sea, and the Indian Ocean; and then for enslavement and retention of captives within the African continent, especially in the nineteenth century. The chapter concludes by providing new estimates for the decennial flow of captives in each of these major categories. For these estimates, like those in Chapter 8, error estimates are calculated. In addition, initial steps are proposed in explaining why the new estimate gives higher totals than previous estimates.

The fourth section, "Results and Review," presents the results of our analysis of populations, migrations, and rates of change, then concludes with a discussion of their implications. In Chapter 10 we present estimates of population by African region for each decennial period from 1890 to 1950, based on calculations with the crude-rates model as described in Chapters 7 and 8. In Chapter 11 we present estimates of population for the same African regions for each decennial period from 1890 back to 1650, based on calculations with the composition-specific-rates model and the updated estimates of captive flows as described in Chapters 7, 8, and 9. The population estimates of Chapter 11 vary in two ways for each region and decade: low, medium, and high estimates based on 95% confidence levels; and variations

[14] For the crude-rate model, the chapter is to conduct a parallel sensitivity analysis drawing (from Chapter 6) on the updated estimates of Saharan, Red Sea, and Indian Ocean volumes of captive exports and of continental enslavement during the nineteenth century.

according to three ways of estimating levels of enslavement and retention of captives within Africa. Despite this range of estimates, the overall population estimates of this book are consistent within a fairly narrow range of estimation. Chapter 12 reviews the historical and social significance of this new understanding of African population size—at once in terms of global comparisons and in terms of its implications for life within Africa.

The results of this analysis differ sharply from prevailing beliefs about African population. Systematic attention to the interplay of major factors in African demographic history over the past five centuries yields a picture that is very different from the pictures that have dominated both the historical literature and the contemporary social-science literature. The picture that emerges here is that of an African population that was relatively large and dense from the seventeenth through the twentieth century, though its growth was hindered and commonly reversed by high levels of mortality and relatively high levels of emigration through enslavement. Emigration through enslavement virtually ended by 1900, mortality declined sharply in the 1940s and 1950s, and populations throughout the continent began a rapid growth unlike anything that had preceded it—a population growth that continues almost unrelentingly until today.

History Backwards and Forwards

The methodology that we are calling "history backwards and forwards" has involved developing our results through a structured alternation between working from present to past and then working from past to present. We think it may have some more general implications for historical methodology, but here we focus on our own procedure. The overall strategy involves checking to see whether our data and interpretation from one period are consistent with those from other periods. First we project backwards, from recent known data to estimate previous data. We work from one decennial point to the previous one, accounting for factors of growth and decline as we can for each of the periods between these points. Then we work forward, decade by decade, with the simulation of population and migration, checking to see if the population at the end point (the most recent date) corresponds to that with which we started. If necessary, we repeat the procedure until the estimates are consistent, going backward and forward. As a concluding step, we articulate a narrative of the changes as we understand them to have happened, moving forward in time.

A simple but important example of the benefits of using this procedure is the recognition that scholars analyzing precolonial African populations, working within the period before the twentieth century, had not paid attention to the recently improved and increased population figures for 1950 and thereafter. As a result, analysts of earlier times failed to notice that they had assumed African populations for precolonial times that were far too low. By declining to link estimated precolonial populations to known national-era populations, they failed to see that they had implicitly assumed African growth rates that were unreasonably high. So a basic lesson of "history backwards" is that one should ensure that descriptions for earlier times are not inconsistent with known data for later times. Similarly, a lesson of "history forwards" is that a historical narrative requires tracing the main steps moving forward in time, preferably with explanation of the reasons for change.[15]

[15] Notes on history backwards and forwards.

The approach of "history backwards and forwards" extends not only to the chronological periods of study but also to the ordinal logic of analytical tasks. That is, social-science analysts traditionally conduct their work starting from "data, variables, assumptions" and proceeding to analysis and empirical conclusions. The approach here will complement that established logic with the inverse logic of reconsidering assumptions and variables in the light of empirical results, and even seeking out new variables to analyze.[16] As with the temporal "backwards and forwards," this analytical backwards and forwards repeats the exercise until the results are internally consistent going both ways.

[16] Example of alternating between starting with data and assumptions and working toward conclusions vs. starting with conclusions and identifying consistent data and assumptions.

Chapter 2

Population and Migration: Previous Estimates

Africa: Continental Population Estimates, 1500 - 2000
The National Era (1950 – 2000)
The Colonial Era (estimates 1900 – 2000)
The Precolonial Era, before 1890
African Population before 1650
African Population in Global Context, 1650 - 2000
African Migration: Estimates, 1500 – 2000
Migration in national and colonial eras, 1890 – 2000
Atlantic Slave Trade, 1450 – 1867
Slave Trade from Northern and Eastern Africa
Slave Trade and Migration within sub-Saharan Africa
The Atlantic Slave Trade Databases, 1999 and 2010
Conclusion

This chapter, along with the succeeding chapter, reviews the previous work on African demographic history—in precolonial, colonial, and national eras—and the methods used for each. For each of these periods, the discussion reviews and comments on the analyses conducted up to the year 2014, identifying their strengths, weaknesses, and the degree of consistency of various studies. The first half of this chapter focuses on past estimates of the stock of population within the limits of the African continent; the second half addresses the flow of captive Africans across the oceans and the Sahara Desert. The next chapter, Chapter 3, addresses the combinations of population stocks and flows used to estimate the impact of slave trade on African population before 1900. As will become clear, the attention given to various periods and regions has varied sharply, and the methods of estimation have varied equally widely.

Africa: Continental Population Estimates, 1500 - 2000

The National Era (1950-2000). African populations in the national era are known in considerable detail. Although most of Africa still does not benefit from regular and systematic enumerations of whole populations, knowledge of African populations has advanced greatly since 1950 through the careful comparison and linkage of an expanding number of surveys and censuses. Estimates reported here for 1950 and after are the 2006 estimates of the United Nations Population Division, although these figures rely in turn on repeated reconsideration of data collections and analyses since 1950.[17]

[17] Through the work of the UN Population Division, documentation on populations since 1950 has been reworked repeatedly, so that updates as recently as 2012 have revised estimates for 1950 and all the years thereafter. www.un.org/esa/population/unpop.htm.

Table 2.1. African Population in the National Era: United Nations Estimates[18]

	Population 1950	Population 2000	Average Annual Growth Rate 1950-2000 (%)
Africa	220,263,472	817,673,000	2.66%
Sub-Saharan Africa	176,150,472	676,586,000	2.73%
West & Central Africa	90,027,000	336,684,000	2.67%
East & Northeast Africa	70,446,595	275,296,000	2.76%

As shown in Table 2.1, the total population of the African continent has now been estimated authoritatively at over 800 million for the year 2000 and at roughly 220 million for the year 1950. These figures for Africa's national period confirm a remarkably rapid rate of growth averaging well over 25 per thousand per year (2.5% per year), brought especially by declining death rates. The expectation of life at birth rose, for sub-Saharan Africa as a whole, from 36.7 years (1950-54) to 48.6 years (1990-94), though it declined thereafter, especially in response to the HIV/AIDS epidemic.[19] This knowledge has been summarized in two comprehensive articles by Dominique Tabutin and Bruno Schoumaker, one focusing on sub-Saharan Africa and the other centering on North Africa and the Middle East.(Tabutin and Schoumaker 2000, Tabutin and Schoumaker 2005)[20] The present description of African continental population since 1950 relies primarily on these two articles.

For historical background to African population before 1950, Tabutin and Shoumaker reproduce the main estimates published in the 1930s, which are presented and discussed in the next section of this chapter. But with regard to the prevailing notion of Africa as an underpopulated region, they perform calculations that portray African settlements as dense and African agricultural work as highly productive.

> Africa, with its fifty countries and their extremely unequal land areas, has for a long time been considered under-populated, and believed to possess huge unoccupied or unexploited areas. . . . By recalculating the densities, as we did, based on the surfaces of arable land and permanent crops . . ., the perspective changes completely. For example, densities rise in Mauritania from 3 to 529 inhabitants per sq. km., in Senegal from 48 to 391, in Kenya from 53 to 676, in Somalia from 14 to 817. Africa thus appears to be far from under-populated, in terms of farmed or cultivable land.(Tabutin and Shoumaker 2000, pp. 466 - 467)

Indeed, this comparison could be expanded. Even including the desert and other non-arable regions in the area of Africa, the surface area of sub-Saharan Africa is over half that of Eurasia, and sub-Saharan Africa's population is roughly one-fifth that of Asia. As a result, overall, Africa's population density is 40% that of Eurasia; African population density is also significantly greater than that of the Americas.(Manning 2014)

[18] Source : United Nations Population Divison, "World Population Prospects: The 2006 Revision."
[19] Expectations of life at birth declined to levels near those of 1960 by 2000 in much of Southern Africa.
[20] For an authoritative overview of advances in demographic studies of Africa, see van de Walle et al. 1988.

Tabutin and Shoumaker emphasize the diversity in post-colonial demographic patterns of African countries. To provide an overall categorization, they offer four main patterns of change in African national populations from 1950 to 2000.(Tabutin and Shoumacher 2000) First is what they call the "traditional pattern," exemplified especially by Mali, in which mortality has declined but birth rates remain at very high rates of 45-50 ‰. Other nations following this pattern include Niger, Burkina Faso, Guinea, Angola, Congo-Brazzaville, Chad, Uganda, and Somalia. Second is the pattern of "classic change," exemplified especially by Ghana, in which declining mortality led after several decades to fertility decline and then to declining rates of population growth, correlating with improved population welfare. Other nations sharing this pattern include Senegal, Gambia, Gabon, São Tome, Comoros, Sudan, and Eritrea. Third is the "AIDS-perturbed pattern," for which Zimbabwe stands out. In this case, a decline in mortality and then in fertility was interrupted by a sharp increase in mortality and sometimes a collapse of population growth. This has been the case for all of Southern Africa and also for Kenya, Malawi, Tanzania, Zambia, Côte d'Ivoire, Cameroon, and Central African Republic. Finally is the pattern of the "war-perturbed model," exemplified by Liberia, in which a brutal increase of mortality resulting from conflict led to impoverishment and in some cases growth in AIDS. Other countries sharing this pattern are Sierra Leone, Democratic Republic of Congo, Burundi, and Rwanda.

These details on African population at the end of the twentieth century owe much to the careful assembly of data by analysts at the United Nations Population Office, but they owe at least as much to workers in the field who, in two or three earlier waves, developed the procedures and the practice of demographic research in Africa. John C. Caldwell, the distinguished Australian demographer, participated in West African demographic surveys and demographic analysis from the 1940s, and continued to write incisive observations on the study of African demography in the early twenty-first century. Overall, demographic study of Africa declined in the 1970s both because of political conflicts within Africa and because of the rapidly increasing debt burdens on African governments of that era. In the 1980s there was a return to expansion of demographic surveys and the beginning of regular national censuses for some countries.

Professional-level demographic study of African societies thus got its start at the end of the colonial era and in the first years of African national independence.[21] That brief era of optimism and ability to invest in social services brought sample censuses and occasional general enumerations, which in some cases—especially for Ghana—still serve as an effective demographic baseline.(Okonjo 1968, Gil and de Graft-Johnson 1964)[22] The summary reports of the United Nations Economic Commission for Africa (UNECA) in the 1960s provided the first systematic overview of African population.[23] A comparison of summary estimates by UNECA (1960s) and UN Population Office (2006) conveys the advance in demographic knowledge

[21] For major collections of demographic analysis conducted during the era of decolonization, see Barbour and Prothero 1961, Brass et al. 1968, Caldwell 1968, Caldwell and Okonjo 1968. See also Coale and Demeny 1983, and Moss and Rathbone 1975.

[22] The Nigerian census project under Chukuka Okonjo was technically adept but its work was undermined by the needs of political leaders to have census results that would strengthen them in determining representation in the federal government. Thanks to John C. Caldwell for discussion on this point.

[23] United Nations Economic Commission for Africa 1968; United Nations, *World Population Prospects*.

accumulated in the past half century: it shows that the UNECA estimates were an improvement over previous colonial-era estimates, but that the UN Population Office has brought further improvement of the UNECA estimates.[24]

Table 2.2. African Population Estimates for 1960: UNECA (1960s) and UN Population Office (2006)[25]

Region	1960 Population: UNECA	1960 Population: UNPO
North Africa	54,274,000	55,869,000
West Africa	88,127,000	80,067,000
Central Africa	34,878,000	32,109,000
Southern Africa	21,613,000	20,813,000
East Africa	44,450,000	39,355,000
Northeast Africa	37,146,000	50,367,000
Africa	278,829,000	277,935,000

The differences between the contemporaneous estimates of UNECA and the retrospective estimates of UNPO indicate the progress that has been made with systematic review of available evidence. In sum, these results demonstrate that the full understanding of the size of African population in 1950 and 1960 was not available until after 2000, and only then did the implications of this result begin to percolate more broadly.

***The Colonial Era (1890 – 1950)*.** Going back to the preceding era—that of European colonial rule—we can now gain an understanding of the gradual process by which estimates of African populations developed. To do so, this discussion will work largely from the end of the colonial period back to its beginning. After World War II, European colonial powers greatly expanded their investment in scientific study and social welfare for their African colonies. On one hand, they sought to strengthen the colonies as resources to support the metropolitan government and economy. In a second point, virtually all Asian colonies had gained independence in the 1940s, so that the African colonies now became the most prominent part of European empires. Thirdly, the worldwide, postwar consensus calling for attention to social welfare became linked with the growing critique of racial hierarchy, thus encouraging greater investment in African social services. Still, in most cases these investments in roads, ports, dispensaries, schools, and government surveys were funded not by subsidies or transfers of funds from the metropole but by increased tax assessments on African subjects. In any case, colonial governments supported the first serious demographic surveys in the 1940s, and such surveys formed the base of the demographic work taken up by the new national governments.[26]

Prior to these postwar demographic surveys, population data that were collected in colonial Africa consisted overwhelmingly of administrative estimates made for tax-collection

[24] [Summarize the UNECA publications and estimates]
[25] For UNECA figures, 1967 populations are projected back at 7 years using annual growth rates provided in the 1968 Demographic Handbook for Africa, 13-15, 22-24.
[26] [Identify the main late-colonial surveys]. The materials in this section were published earlier, in a different form, in Manning (2010).

purposes. These were almost never enumerations, but were often estimates of numbers of households in each region. Most African governments in the colonial era did not publish regular population data: an exception is the government of South Africa, which published populations in its statistical annuals, although these population totals also appear in general to be too small.[27]

Caldwell and Schindlmayr, in their 2002 article, identified the consensus that coalesced, especially in the 1930s, on the size of current and historical populations of Africa.(Caldwell and Schindlmayr 2002) In response to a League of Nations call to develop worldwide population estimates, Walter Willcox and others reviewed historical estimates and contemporary records and developed estimates that have been used ever since. Table 2.3 displays the remarkable closeness of four major estimates of African continental population in the early 1930s. Caldwell and Schindlmayr emphasize that the estimates can only have been this close to one another because the analysts were drawing on the same earlier estimates, since there existed no collection of empirical detail on African population that could be aggregated.

While the principal purpose of their article was to demonstrate that this consensus was mostly self-reinforcing, Caldwell and Schindlmayr also made the case that colonial estimates of African population were systematically too low.(Caldwell and Schindlmayr 2002) This insight encouraged the present authors to focus seriously on linking the known population figures for national-era Africa with colonial-era African population figures, to see whether the latter were plausible or implausibly low. Table 2.3, in its right-hand column, displays the average annual rate of African population growth that would have been required for each of the estimated levels in the 1930s to grow to a population of 220 million in 1950. These rates of over 2% per year were simply impossible in the demographic conditions of the 1930s and 1940s, and demonstrate that the estimates of roughly 140 million Africans in the early 1930s were simply too low. Such growth rates have been documented almost nowhere in the world for that time period, though they are not uncommon for Africa in the post-DDT years of the 1950s and 1960s. This comparison demonstrates the need for new estimates of colonial-era African populations. (As we will see below, exceptions have been documented for French Equatorial Africa and the West African savanna under French rule.)[28]

Table 2.3. Colonial-Era African Populations: Various Estimates.
Source: Sources: Willcox (1931), 78; Carr-Saunders (1936), 18, 34-35; Kuczynski (1948), 1.[29]

Year	African Continental Population	Source and Year of Estimate	Annual Growth Rate (%) to 1950 Population of 220 million
1929	140,000,000	Willcox (1931)	2.28%
1930	145,400,000	League of Nations	2.20%
1930	143,315,000	Carr-Saunders (1936)	2.28%
1934	145,074,000	Kuczynski (1937)	2.78%

[27] South African annuals.
[28] See note 30 below.
[29] For other estimates of African continental population, see Maddison, *World Economy i(date?)*; Biraben 2003, McEvedy and Jones, and Durand 1967.

The clear judgment of recent authorities is that colonial-era population estimates systematically underestimated the size of African populations: low estimates of African population characterized censuses in South Africa as elsewhere on the continent.[30] Several related types of bias kept estimates low, and these downward biases had not been overcome even by the end of the colonial era. First, officials estimating populations did not visit or estimate for all the regions within their territory. Second, they gave prime attention to counting taxable male adults. Third, when they included female adults, they still tended to underestimate the number of children. Fourth, where populations were dispersed, many households were left out even in areas enumerated. Colonial officials sought to use rules of thumb – ratios of family size per house or per head of household – but these did not generally overcome the downward bias.

On the other hand, some areas under French rule were exceptions to this pattern. In West Africa, the savanna and sahelian territories that are now Mali, Burkina Faso, and Niger may have been overestimated in population, and the Central African territories that are now Central African Republic, Gabon, and Congo-Brazzaville were similarly at risk to overestimates in population. The analyses of Dennis Cordell, Joel Gregory, and Raymond Gervais are distinctive in making the case for colonial overestimation rather than underestimation of population in these territories.[31] At the same time, these studies are among the most detailed in arguing that colonial records exaggerated the rate of growth of African populations—a conclusion that is implicit in the work of all recent scholars on African population.(Cordell 1993)[32]

Further, recent authorities appear to agree that colonial population estimates were often erratic and arbitrary. Annual repetitions of unchanging population figures for a region or, more commonly, annual growth at an unchanging rate provide the most common examples of arbitrary reporting. Ratios of family size per household varied sharply by year and from official to official.[33] Shifts in territorial organization compounded the inconsistencies in reporting. Tabulating and aggregating colonial estimates does not in itself provide any way of checking or correcting these distortions. As a result, the alternative adopted here—an independent estimate calculated by projecting back from 1950 population estimates using hypothesized growth rates—has some clear advantages as a way of estimating African populations before 1950.

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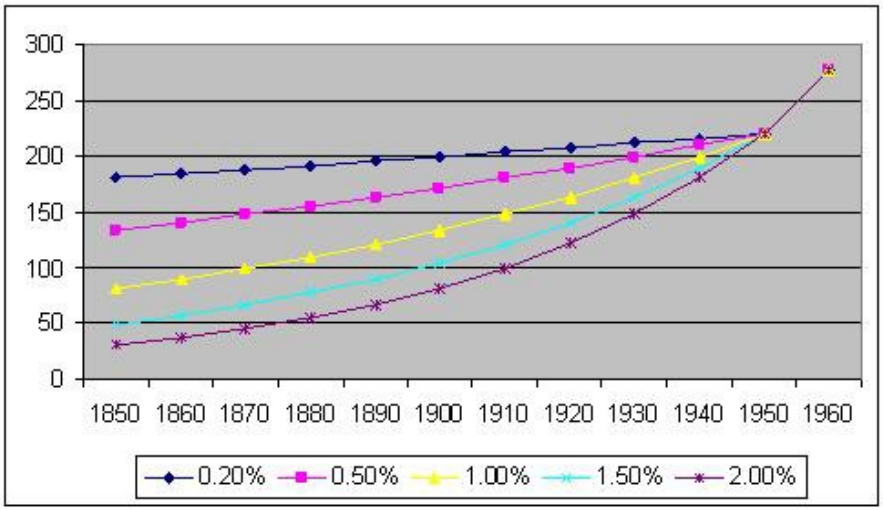
[30] On the underestimates of colonial African censuses, see Caldwell and Schindlmayr 2002, Tabutin and Schoumaker 2000, and Fetter 1990b. In South Africa, enumerations of populations designated as European, Indian, and Coloured were fairly accurate in the early twentieth century, but African populations were underestimated there as elsewhere until mid-century.

[31] On the population of French West Africa, especially colonial Upper Volta, see Cordell and Gregory 1982, Gervais 1983, Cordell and Gregory 1983, Gervais 1993, and Mande (date?). On French Equatorial Africa, see Cordell 1993, and Gervais 1993. See also Headrick and Austen; Coquery; and Sautter 1966.

[32] In fact the population growth rates of Gabon, Congo-Brazzaville, and Central African Republic have remained relatively low in the national period. In contrast, those in the West African sahel rose to comparatively high levels after 1950.

[33] In Ruanda-Urundi under Belgian rule, from the 1920s through the 1940s, the administration made efforts to enumerate adult males, then estimated total population by multiplying the adult-male total by a factor set for each year, estimating the ratio of total population to adult males. For Burundi, this factor ranged from a low of 3.602 in 1931 to a high of 4.649 in 1935—a difference of almost 30% within four years. *Rapport sur l'Administration Belge du Ruanda-Urundi* (Brussels: Etablissements Généraux d'Imprimerie).

Figure 2.1: African Population at Constant Growth Rates, 1950 back to 1850.



In an heuristic device, Figure 2.1 compares the known African continental populations of 1950 and 1960 with speculative African populations in earlier decades, assuming the indicated annual growth rates of from 0.2% to 2.0% per year. Inspection of the results suggests that only the lowest growth rates, averaging well under 1% per year, could conceivably fit with the reality of African population size and growth after 1850. That is, one can be certain that African population growth accelerated shortly before 1950.

For the period from the 1930s to the 1960s, colonial reports on population are relatively comprehensive, including some censuses and commonly including useful qualitative descriptions of population characteristics such as migration. Prior to the 1930s, from the beginning of the twentieth century through the 1920s, colonial statistics are scattered, but may include qualitative descriptions and useful comments on migration. Small colonies and urban areas, such as Gambia and Lagos, tended to have the best reports. For the nineteenth century, some statistics are available for the limited regions under colonial rule, such as Natal and parts of Senegal, but for most of the continent one is left with guesswork. During the last half of the nineteenth century, populations were disturbed by large-scale enslavement and migration in many areas of the continent, making them more difficult to estimate. On the other hand, imperial and colonial observers recorded useful estimates of the volume of slave trade in that era.

For the colonial era overall (roughly 1890 to 1960), three types of new data are enriching our understanding of African populations. First, the documentation of post-colonial populations sets methodological standards and empirical figures to which the colonial-era estimates must be linked. Second, there have been numerous studies of the colonial era, which rely on exploration of published colonial documents and the surveys underlying them (although there has not yet been any attempt to aggregate these studies into global population estimates for the colonial

era).(Cordell and Gregory 1994, Fetter 1990)[34] Third, the comparison of colonial African data with the expanding knowledge of contemporaneous data from other parts of the world provides a basis for making improved estimates of African demographic rates.(Maddison 2001)

The Precolonial Era (before 1890). For the long period of time before the twentieth century, analyses of African population are rare and poorly backed up with empirical evidence. In this brief section, the full precolonial era back to 1650 is considered at once, because of the similarity in the style of estimates throughout that long period.[35] Caldwell and Schindlmayr show that speculative estimates began with the continental figure of 100 million proposed in c. 1650 by the Italian Jesuit scholar Riccioli. They also document the seventeenth-century estimates by Vossius, William Petty, and Gregory King; the detailed mid-eighteenth century review by the Prussian scholar Süssmilch and the adoption of much of his work by Malthus in the early nineteenth century; and additional work by nineteenth-century scholars Dieterici and Supan (the latter also Prussian).(Schindlmayr and Caldwell 2002) In the twentieth century the League of Nations and later the United Nations supported estimates of world historical populations: Knibbs, Willcox, and Carr-Saunders each proposed estimates drawing especially on the same sources, and R. R. Kuczynski developed African population estimates. Later on, Cipolla, Clark, Durand, McEvedy and Jones, and Biraben developed estimates of world and continental population, including totals for Africa.[36] Some additional studies were done on certain regions, most notably the Wrigley-Schofield study of English population history (1981) but also additional reviews of Chinese population history.[37] At the beginning of the twenty-first century, Angus Maddison offered a comprehensive set of global population estimates, although these in fact added very little to the figures proposed by Willcox in the 1930s.

Beginning with Riccioli's estimate of 100 million people in Africa in 1650, the majority of authors assumed African populations of roughly that same level, and assumed that Africa experienced little if any population growth until the twentieth century. After World War II, however, as the knowledge expanded about contemporary population growth, it became easier for scholars to presume a long-term process of African population growth, rather than stagnation. As a result, the populations estimated for Africa in the seventeenth and eighteenth century became steadily smaller. In effect, the more recent writers assumed that slave trade had no significant negative effect on African population (McEvedy and Jones 1978, Maddison 2003).

The same question must be posed again for the nineteenth century. Especially with the wide attention given to David Livingstone's report of massive enslavement and heavy loss of life in eastern and southern Africa in the 1860s and 1870s, there grew a tendency to conclude that nineteenth-century African population declined as a result of slave trade.(Livingstone 1866, 1874) Carr-Saunders, for instance, suggested in 1936 that the continental population fell to 90 million in the nineteenth century. Postwar scholars, in contrast, having largely set aside the

[34] The present study develops continental estimates, but does so deductively from aggregate populations and estimated growth rates, rather than inductively through aggregation of local studies.
[35] In our own analysis in later chapters, however, we break this period into two, according to the changing character of enslavement: the era from 1650 to 1790, in which the export slave trade governed the overall level of enslavement in Africa, and the era from 1790 to 1890, in which continental enslavement grew substantially even as export slave trade reached its maximum and declined.
[36] Additional estimates at global and continental levels. Schindlmayr and Caldwell? Individual citations?
[37] Latin American estimates, Chinese estimates, Wrigley & Schofield (citation).

stories of mass enslavement in nineteenth-century Africa, became ready to accept the notion of increasing African population in the late pre-colonial and early colonial eras. John C. Caldwell, active in the work of documenting African population as its growth rate accelerated in the postwar era, developed an impression of steady growth and expansion in African society, and was ready to project it into the past. While his work was pathbreaking in demonstrating the availability of documents and the relevance of such analysis, our review of his analyses shows that his estimates of rates of natural increase in precolonial times were too high.

From the 1960s, a new and more interactive argument was added to the case for African population growth. The era of Atlantic connection brought the cost of enslavement but, as Marvin Miracle and Philip Curtin argued, also brought the arrival of new foodstuffs from the Americas, especially maize and manioc.[38] Numerous writers leapt to the conclusion that new food crops enabled African populations to grow despite the losses to enslavement. Nevertheless the research, at this point, is simply inconclusive on the rates of birth and death in seventeenth-century Africa, on the demographic costs of enslavement, and on the timing and nutritional impact of the spread of new crops in the continent where humanity arose long ago.(Curtin 1969, Caldwell 1985, Manning 1982, Wigboldus 1986)[39]

African population before 1650. For Africa before 1650, the documentation is even scarcer. We are mostly limited to archaeological results. Written Portuguese documents go back to1450, but these were mostly limited to the coast and have not been studied in full detail. Several authors have offered speculative projections for this early period: most of them assumed a steadily growing population.(Caldwell 1985, Maddison 2001, Cordell, Biraben 2003) Walter Rodney, in a well-known article on the Upper Guinea Coast in the sixteenth century, argued that European contact brought expansion of enslavement and population decline.(Rodney 1966) Louise-Marie Diop Maes, in expanding a parallel argument, used indications of archaeological sites to argue that West African populations were very dense until the era of European arrival on the coast. In arguments based on archaeological research in Southern Ghana addressing the eleventh through fifteenth centuries, it has been suggested that Southern Ghana suffered a sudden and severe decline in population in the mid-fourteenth century—the same time as the Black Plague as documented for Asia and Europe.(Chouin and Decorse 2010) This raises the possibility that populations in much of Africa might have declined sharply as a result of plague, and that they subsequently rose at a relatively rapid rate (such as between 0.5% and 1% per year), much as did European populations of the era.

African Population in Global Context, 1650 - 2000

Where has African population fit into that of the world as a whole? The inconsistency of sources makes it difficult to be confident of the relative density of population in various world regions over time.[40] While written documents from certain regions provide us with specific demographic data for as much as two thousand years ago – the Mediterranean, Western Europe, and China – for other regions we must rely on a more complex mix of evidence from archaeology, written sources, and other evidence.

[38] Miracle 1966, Curtin 1969. Citations and repetitions of this argument. Critique of the argument (Manning),
[39] Only in China are we beginning to get information on the details of new crops and their addition to caloric intake.
[40] Discussion at Amsterdam meeting on continental populations, October 2013.

Population estimates for parts of the world beyond Africa have gone ahead, mostly with better documentary bases.(Maddison 2001) In the occasional world-wide summaries of population growth, recent research on African populations has been given little attention. European population estimates are fairly consistent, because of their strong documentary base, yet there are variations especially in figures for Eastern Europe, stemming from disagreements on the size of past populations and disagreements on which areas to include within "Europe." For Asia, the best available records are for the population of China, but even these are debated, since censuses and population registries sometimes focused on heads of families rather than on actual

Table 2.4. Comparison of Continental Population Estimates

Source: Table 2.4 source: Maddison (2001), 175, 183. Maddison's "Western Offshoots" include the United States, Canada, Australia, and New Zealand; "Europe" includes the entire territory of the former Soviet Union.[41]

Date	Africa	Americas	Europe	Asia
Source				
2000				
Maddison (1998)	760	550	799	3516
McEvedy	385 (1975)	545 (1975)	635 (1975)	2300 (1975)
Biraben	800	819	782	3631
1950				
Maddison	228	342	572	1382
McEvedy	205	325	515	1450
Biraben	-	-	-	-
1900				
Maddison(1913)	125	191	340	977
McEvedy	110	145	390	970
Biraben	118	165	422	902
Willcox	141	142	401	859
1820				
Maddison	74	32	222	710
McEvedy	70 (1800)	24 (1800)	180 (1800)	625 (1800)
Biraben (1800)	101	24	195	646
Willcox (1800)	100	25	187	522
1700				
Maddison	61	14	126	402
McEvedy	61	13	120	415
Biraben	106	12	125	436
Willcox (1750)	100	12	140	406

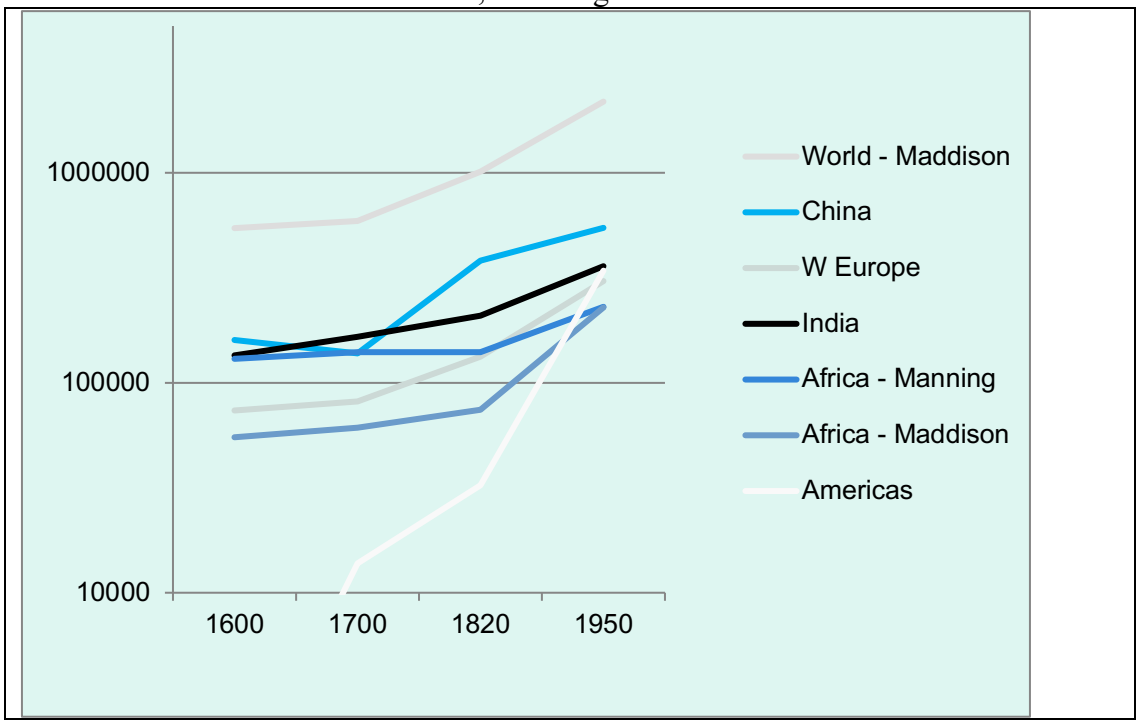
individual counts. Meanwhile, other areas of Asia – Southeast, South, Central, and West – lack precise population counts for all but scattered regions during the nineteenth century and

[41] Growth rates in Table 2.4 were calculated by the authors.

especially before, so that estimates of overall Asian population vary widely. For the Americas, it is known that population declined sharply in the sixteenth and early seventeenth centuries in response to waves of disease, but the precise populations are not known. From the mid-eighteenth century American population rose in response to increasing immunity to disease, and especially because of rising migration from Africa and Europe. From the nineteenth centuries, American populations are known with a precision exceeded only by that for Europe. Thus, while African populations are not known in great detail before 1950, this rapid survey suggests that the vagueness of estimates of African population is not greatly different from the vagueness in estimates of population for Southeast Asia and Central Asia before 1850, for South Asia before 1800, and for the Americas before 1750.

Angus Maddison's global estimates reaffirmed the common assumption that African population was marginal on a world scale but was growing at a rapid rate in both precolonial and colonial eras: he assumed African growth to have averaged 0.86% per year from 1820 to 1950. But a closer inspection of these same summary figures suggests some obvious corrections to the assumptions it entails. The only regions with growth rates estimated at over 1% per year were South America and "Western Offshoots" (North America and Australasia)—regions known to have received massive numbers of immigrants. Europe showed a growth rate of nearly 1% and was undergoing significant out-migration in the nineteenth century, but this was also the era of the European demographic transition, in which death rates fell at an unprecedented rate. No reason was given as to what propitious African conditions allowed for growth rates nearly double those of Asia. On the face of it, therefore, Maddison's estimates for African population size in the nineteenth and early twentieth centuries were unreasonably low.

Figure 2.2. Estimates of Continental Populations
Source: Maddison, Manning-Nickleach



African Migration: Estimates, 1500 – 2000

Population and migration have often been accounted quite separately. A population count gives the stock or number of people in a region at a given moment; a migration count is the flow or number of people crossing a boundary within a selected period of time. Demographers were long reluctant to include migration in the study of population, as the migratory additions to and subtractions from regional populations brought serious complications to analysis. Census-takers, in contrast, commonly made efforts to include migration estimates, so that censuses are among the most valuable documents on historical migration.[42] Only in recent decades have academic demography and migration studies come to be closely linked, and our study follows this trend: we seek to link African population and migration systematically over time. We begin by summarizing previous estimates of levels of African migration that have taken place during the past five centuries. The various segments of African migration have been accounted and debated more separately than together. That is, studies of slave trade have focused on people carried out of the continent, in isolation from study of the migration of people within the continent. The export slave trade itself has been documented and analyzed as separate stories for the Western Coast of Africa, the Indian Ocean coast, and for northern Africa. This section is to begin by assembling the various existing records on African migration, so that they can be compared and linked more fully with the story of migration elsewhere in the world – a story that is only now being assembled as an example of the interconnections that create world history.

Migration in national and colonial eras, 1890 – 2000. For readers of the global literature on migration, it may appear that African captives, traveling across the oceans on sailing ships, dominated migration worldwide until roughly 1850, when African migration halted and a new and larger stream of migration arose among Europeans and Asians traveling by steamship. While it is true that overseas migration of Africans in captivity declined significantly beginning 1850 and virtually halted by 1900, the overall migration of Africans did not halt. Six distinctive streams of African migration rose and fell in the period from 1850 to 2000. First was the continental enslavement of Africans, which rose from the end of the eighteenth century, peaked in the late nineteenth century, and ended in the early twentieth century. Second was the set of migrations of African populations in response to the establishment of colonial frontiers and the imposition of colonial police and military control in the era up to the end of World War I. Third was large-scale labor migration, often provoked and enhanced by the collection of taxes as well as recruitment, which sent especially men but also women to leave their homeland and move temporarily or permanently to centers of mining, export-oriented agriculture, or urban centers of manufacture and services.[43] Fourth, following decolonization and the emergence of political struggles and wars within independent African states, refugees fled their homes to cities, distant regions, or neighboring countries. Fifth, in later years of the twentieth century, migrants left Africa in growing numbers—this took the form of a brain drain for those who were well educated, and the search for low-wage labor in Europe or Asia among those treated as low-skilled workers. Finally, overlapping all of these changes was the process of urbanization within

[42] Examples of British, American, and other censuses.

[43] Dig out labor migration studies from the **Stanford bibliography**. Tabutin & Shoumaker; Gregory and Piché. Freund, South Africa (mines); Congo (Northrup, Fetter, others).

Africa, which developed slowly in the early twentieth century and then accelerated massively at the end of the century.[44]

Of the points highlighted in the preceding paragraph, several will need ultimately to be explored in detail in order to provide a balanced and thorough review of African migration. Enslavement rebounded significantly within Ethiopia during the first three decades of the twentieth century (Fernyhough 2010). The numerous stories of colonial-era cross-border migration have been told in a range of localized studies, among which that of Asiwaju (1974) stands out. The large-scale story of colonial labor recruitment, especially for the mines of southern and central Africa but also for agricultural projects in Sudan and throughout West Africa, needs to be retold as a chapter in migration history (Freund, Cordell et al.). Finally, a wave of international African migration began with students in the 1950s and expanded steadily into the twenty-first century.(Okpewho).

It may be the case, however, that aggregate African migration really did decline sharply in the late nineteenth and early twentieth centuries. Arguably, African societies were exhausted and drained by the loss of so many migrants and especially by the generally brutal means by when families were torn apart by migration. To this earlier migration through enslavement we now turn.

Atlantic Slave Trade, 1450 - 1867. In the 1950s and 1960s, African decolonization movements combined with North American civil rights movements to provide an impetus for expansion in African studies and for reconsidering the history of slavery and slave trade. Philip D. Curtin published a 1969 estimation of the volume of slave trade that fit explosively with this expanding interest. In a work that he described as "an intermediate level of synthesis," he compiled the best available estimates of the volume of Atlantic slave trade, according to the various European and American national carriers, and concluded that some 9.8 million Africans (± 20%) had been delivered in captivity to the Americas in the years up to 1850. This work brought excitement, controversy, and a great deal of additional work intended to test and extend Curtin's estimates.[45]

Curtin's proposed total was considerably lower than the figures most commonly cited in previous work. Curtin's historiographical introduction to his 1969 book was thus of considerable importance. In it, he showed that the commonly cited figures of from 15 to 30 million persons shipped across the Atlantic were based on simple guesswork, though at least one careful estimate had proposed roughly 12 million Atlantic embarkations of captives.(Deerr 1949) The problem was that of a consensus replicated across time without detailed verification—a problem similar to that of the estimates of African continental population. Over forty years of additional research have unearthed many important details and have added measurably to Curtin's estimate of the volume of the Atlantic slave trade, yet have confirmed the validity of his research design. It is now estimated that roughly 10.5 million persons reached the Americas in captivity before 1860,

[44] Ultimately we want to find rough numbers of migrants within Africa 20th, and compare them to our estimates of migration within Africa 19th. Then we can address the overall question of Africa's long-term migration patterns. Don't forget the insights from Lucassen & Lucassen. Continental migration; extra-continental migration.

[45] Curtin's approach relied on multiple perspectives, estimating numbers of captives transported with a variety of techniques and types of data.

and that roughly 12 million persons boarded those slave vessels, so that some 1.5 million perished en route.(Lovejoy 1989, Eltis et al 2010)

The literature on the export slave trade across the Atlantic – its magnitude and composition – grew up first and has been rather thoroughly reviewed. Almost twenty conferences on slavery and the slave trade were held between 1973 and 1988, in the United States, Canada, Britain, France, Denmark, and elsewhere.[46] In addition, large numbers of monographic books and journal issues pursued the issue of the size, composition, and impact of the slave trade—focusing especially on the Atlantic, but also on slave trade within the Americas.[47] Outstanding in this monographic work were Jean Mettas, who scoured the archives of French ports to develop detailed and systematic records of eighteenth-century slave trade; Serge Daget, who followed on after the death of Mettas to complete parallel work on nineteenth-century French slave trade; Johannes Postma, who exhaustively researched the Dutch slave trade; and David Eltis, whose initial work coded the reports behind the 1845 Parliamentary Report on slave trade (Mettas, Daget, Postma, Eltis 1980). This remarkable accumulation of data, supplemented by the work of many other researchers, provided the basis for the construction of an overall dataset, work which began in the early 1990s.

Slave Trade from Northern and Eastern Africa, 1650 – 1900. In addition, detailed discussions developed among historians of Africa in the postcolonial era on other dimensions of slavery and the slave trade.(Manning 1996) These included the volume of slave trade across the Sahara, the Red Sea, the Indian Ocean; the further voyages of slaves from their ports of arrival in the Americas to further and distant mainland destinations; the expanding commerce in slaves within the African continent; and the contemporaneous enslavement of people other than Africans, especially in Eurasia.

Ralph A. Austen, an energetic historian of Africa, took up the task of attempting to compile the scattered evidence on the volume and direction of slave trade across the Sahara, the Red Sea, and the Indian Ocean. He tallied the results of deep and eclectic reading into tables, organized by space and time, listing the sources and the qualitative or quantitative indications on enslavement and slave trade in each reference. He then treated these references as samples of the overall slave trade and developed procedures of estimation to transform these scattered references into annual averages of numbers traded for each period and total numbers of enslaved migrants in each period. He also provided estimates of average rates of mortality in this trade. The results suggested that Africa's northern and eastern exports of captives, over the course of a millennium, exceeded the number send across the Atlantic in half that time.

Table 2.5. Global Estimate of Trans-Saharan Slave Trade
Source: Austen 1979, p. 66.

Period	Place	Subtotal	Annual Average	Total (000)

[46] For a review of the quantitative literature on the Atlantic slave trade, see Lovejoy 1982. See also Lovejoy 1989 and Manning 1996. On the earlier literature on the volume of slave trade, see Curtin 1969; see also Rawley 1981 and Inikori 1982.
[47] Slavery & Abolition, JAH, HAHR, Caribbean journals, IJAHS, other Africa journals.

			(000)	
650 – 800			1.0	150
800 – 900			3.0	300
900 – 1100			8.7	1740
1100 – 1400			5.5	1650
1400 – 1500			4.3	430
1500 – 1600			5.5	550
1600 – 1700			7.1	710
1700 – 1800			7.1	715
	Egypt	290		
	Libya	100		
	Tunisia	50		
	Algeria	25		
	Morocco	250		
1800 – 1880			14.5	1165
	Egypt	510		
	Libya	300		
	Tunisia	50		
	Algeria	40		
	Morocco	265		
1880 – 1900			2.0	40

Austen also sought to distinguish between the number of captives sent across the Sahara or the ocean and the number who survived the voyage. For the trans-Saharan voyage, he assumed an additional 5% desert edge retention and 20% mortality for trans-Saharan crossing.

Table 2.6 Projections for the Total Red Sea Slave Trade
Source: Austen (1979), 461

Period	Demand Factors						Total
	Yemen/ Hijaz	South Arabia	Persian Gulf	India	Med.	Per Annum	
650 – 850	1	1	0.5	0	0	2,400	484,000
850 – 1000	1	1	1.5	0	1	3,300	489,000
1000 – 1200	2	1	1.0	0	1	3,400	340,000
1200 – 1500	1	1	1.0	2	1	3,100	931,000
1500 – 1700	2	1	1.0	2	1	4,500	909,000
1700 – 1830	1	1	1.0	1	1	4,500	650,000
1831 – 1885	3	1.5	1.5	2	8.5	5,500	303,000
1886 - 1920	1	1	0	0.5	0.5	1,600	22,000

For the Red Sea trade, crossing from the Nilotic Sudan and from Ethiopian and Somali ports of the Horn of Africa, Austen compiled a similar set of estimates, developing a set of ratios of the absolute and relative number of captives brought in to the various Arabian and Asian ports.[48]

Table 2.6a. Austen on Red Sea Trade: decennial totals.
Source: Austen in Clarence-Smith, p. 33.

	Aden	Massawa	Danikil	Suakin	p.a.	Red Sea
1800	28,000	11000		12000	5100	51,000
1810	28,000	15000		12000	5500	55,000
1820	28,000	15000		12000	5500	55,000
1830	28,000	15000		12000	5500	55,000
1840	28,000	15000		12000	5500	55,000
1850	28,000	15000		12000	5500	55,000
1860	28,000	15000		10000	5300	53,000
1870	28,000	8000	6000	10000	5200	52,000
1880	21500	1000	18000	5000	45500	45,500
1890	5000	1000		5000	1100	11,000
	250,500	111,000	24,000	102,000		487,500

Table 2.6b. Austen on Swahili Coast Trade: decennial totals.
Source: Austen in Clarence-Smith, p. 31.

	Zanz/Kilwa	Kilwa	Kilwa - Moz	smuggling		Swahili
1800	40000					40000
1810	40000					40000
1820	40000					40000
1830	40000					40000
1840	31000	7500	1500			40000
1850	10000	25000	5000			40000
1860	10000	25000	5000			40000
1870	5000	12500	2500	2500		22500
1880				5000		5000
1890				5000		5000
	216000	70000	14000	12500		312500

[48] In the figures shown in Tables 2.6a and 2.6b, Austen emphasized that the totals listed for 1700 – 1830 and 1886 – 1920 were derived from direct evidence, and not just the indirect estimates of his other figures.

Table 2.7. Projections for East African Slave Trade: decennial totals.
Source: Austen, Campbell

Period	Kenya & Tanzania	Mozambique	Madagascar
1800s	30,000; 0	50,000	15,000
1810s	140,000; 3000	120,000	20,800
1820s	200,000; 7500	200,000	n.a.
1830s	300,000; 7500	200,000	30,000
1840s	200,000; 7500	150,000	35,000
1850s	200,000; 7500	200,000	40,000
1860s	18691; 7500	n.a.	40,000
1870s	200,000; 4200	80,000	40,000
1880s	100,000; 2000	200,000	40,000
1890s	45,000; 2000	n.a.	21,250

For the East African slave trade, Austen limited his estimates to the Swahili coast—the coast of modern Kenya and Tanzania. Only later did Gwyn Campbell, Richard Allen, Pier Larson, and other scholars develop estimates for the additional slave trade, especially from Mozambique and its hinterland, to Madagascar, the Comoros, the Mascarenes and other points of the Indian Ocean; a parallel slave trade from Madagascar fed the plantations of the Mascarenes from the 1670s. Mozambique also continued as a source of captives who were dispatched on Brazilian and Portuguese ships to the Americas in the years up to 1850. In addition, a large-scale process of enslavement arose in nineteenth-century Madagascar, with captives both exported and held within the island, now dominated by the Merina Kingdom.(Campbell 2005, Allen 2005) In sum, Table 2.7 includes not only the estimates of Austen for Swahili coast exports but also the estimates of Campbell and others for Mozambique and Madagascar.

Estimates on the Saharan and Indian Ocean slave trade by Austen and his successors, of necessity, were far less detailed than the Atlantic estimates of Curtin, and the level of scholarly activity in following up Austen's estimates was also far less than for Curtin's Atlantic estimate, especially because of the scarcity and terseness of sources. Nevertheless, additional information has been collected since Austen's initial estimates, especially for the eighteenth and nineteenth centuries, and especially for the Indian Ocean. Frederick Cooper, Abdul Sheriff, and William Gervase Clarence-Smith were active in this work, and Gwyn Campbell was especially active, from the 1990s, in organizing conferences on Indian Ocean slavery that paralleled those that had been held earlier for the Atlantic.[49]

Slave Trade and Migration within sub-Saharan Africa. Tightly and yet obscurely linked to the emigration of millions of Africans in captivity has been the question of enslavement within Africa. Sometimes it is simply neglected, as when the term "the slave trade" is taken to refer uniquely to the export of captives from African shores, without regard to the complex fates

[49] Cooper 1980, Sheriff 1987, Clarence-Smith 1989, Campbell (several). Also those who worked on Ethiopia: Abir (date?) and later Fernyhough 2010.

of those on the continent. More often, it has been assumed that enslavement and mortality within Africa developed extensively, yet there was hardly any way to go beyond episodic descriptions. The accounts of the Scottish missionary David Livingstone, published from the journals of this three voyages through southern and eastern Africa (1852-56, 1858-64, and 1866-71), gained wide fame for documenting the horrendous extremes of enslavement in that era.(Livingstone 1857, 1866, 1874) Other European travelers in Africa—Speke, Burton, Nachtigal, Barth, and others—described many aspects of African societies, including the relatively high levels of enslavement.(Speke, Burton, Nachtigal, Barth.)

Studies of government anthropologists of the early colonial era and later by professional anthropologists of the high colonial era took a different approach. These include empirical detail but are cross –sectional, without a very good idea of change over time. Even more, they were ideologically predisposed to minimizing the extent and oppression of slavery in Africa, especially since colonial governments chose overwhelmingly not to emancipate slaves as they established colonial rule, but instead instituted processes that they believed would reform slavery and lead to its gradual demise.

Then, in the post-independence era, historians and anthropologists took another look at enslavement within Africa, heavily influenced by the growing attention to overseas slave trade. Still, this work did not yield much detail about the capture and migration of captives in precolonial Africa (Meillassoux, Miers and Kopytoff, Miers and Roberts, Robertson and Klein, Harms, Miller, Cordell). While several collective volumes were published, addressing slavery in numerous social situations, there has not been an attempt to summarize the nature, extent, and evolution of enslavement within Africa over time. Chapter 6 of this volume takes the first steps toward such a general review, in order to develop quantitative estimates of enslavement and its attendant mortality that can be made a part of the overall analysis of African population history.

The Atlantic Slave Trade Databases

A Consolidated Dataset, 1999 and 2010. In a major consolidation of research on the Atlantic slave trade, David Eltis and colleagues published in 1999 a dataset on CD-ROM including comprehensive data on all slave-trade voyages available to them.[50] Initially entitled the *Du Bois Institute Database on Transatlantic Slavery* in recognition of the institution that supported its compilation, it was the best data available on the Atlantic slave trade, collected in a massive resource. In this commentary on the first edition of that compilation, it will be labeled the "1999 dataset," in contrast to the later "2010 dataset" published by the same group.[51]

The creation and dissemination of this collaborative work helped to open a new era in research on the history of slavery, and in so doing set a model for social science research in the time to come. In particular, this combined dataset differed from those that preceded it in allowing for systematic comparison or combination of equivalent variables in the various constituent

[50] This "voyage-based" approach counted transatlantic shipment of captives only when they could be attributed to a specific voyage.

[51] This discussion of the 1999 CD-ROM draws on a paper presented at the 1998 conference at College of William & Mary on the CD-ROM (Manning 1998). That paper included identification of some errors and inconsistencies in the dataset which were subsequently corrected.

datasets. This commentary on the 1999 dataset addresses the volume and national participation in the slave trade, but also the region of origin of the captives, their region of destination, and the changes in the trade over time.

Categories, extent, and limits of the data. The data collected in this resource were "voyage-based." The analytical case, as coded and analyzed in the Statistical Package for Social Sciences (SPSS), is an individual Atlantic voyage by a ship. The more than one hundred variables for the dataset are each coded as observations about a voyage. The compilers identified sets of variables according to the type of information they provide:

- the vessel -- its name, captain, registry, tonnage, etc.
- the crew -- their number, mortality.
- the places visited -- ports of departure, African ports for embarking captives, ports for disembarking captives.
- dates -- of departure and arrival at various places.
- the captives -- numbers embarked, age and sex distribution, morbidity and mortality, numbers disembarked.
- the sources of information on voyages -- precise source or sources for each voyage.
- the fate of the voyage -- whether it reached successful conclusion, or was interrupted by natural causes or human agency.

The 1999 dataset, because of its comprehensive scope and its thorough recording of data, provided new evidence on several dimensions of the Atlantic slave trade. It added to our knowledge of individual voyages by noting and combining data from multiple sources. It organized data on the slave trade by individual ports in Europe, Africa and the Americas, and noted the multiple points of trade for individual voyages on both sides of the Atlantic. The dataset was constructed with an emphasis on preserving data on the age and sex of captives. Further, it provided indications of the fate of voyages, and thereby provided important new evidence on the interdiction of slave trade in the nineteenth century. In addition to these variables drawn directly from the sources, the compilers calculated some fifty individual "imputed" variables, which reflect their aggregations of the basic variables or estimates based on certain assumptions.

The dataset was large, and its comprehensiveness exceeded that of any other dataset on long-distance migration. But, as the compilers were careful to note, it was not the whole story of the slave trade. The limits on documentation and applicability of the dataset need to be underscored to ensure that it is not misrepresented. Here are some indications of boundaries and lacunae in the categories for the voyage-based data addressed in this dataset.

First was the boundary determining which voyages and other data were to be included as relevant to this dataset, and which were to be excluded. The compilers agreed to exclude from their dataset (a) sales of captives on the African continent, (b) voyages taking captives to Indian Ocean destinations, (c) voyages taking captives on short-distance Atlantic trips, as to São Thomé, the Canaries, or the Cape Verde Islands, and (d) voyages resulting in sale and resale after disembarkation of captives in the Americas, such as movement of captives from Jamaica to Cartagena and beyond. Second, within these limits, there was the lacuna of unknown voyages. The compilers initially provided data on over 27,000 voyages, but an unknown number of

voyages was missing. Third, for the known voyages, there was the lacuna of missing data on the cargoes of captives. Records on roughly 16,000 voyages provided information on the numbers of captives. Fourth, for those voyages with data on the captive cargo, there was the problem of the quality and consistency of the cargo data. Of the 16,000 voyages providing records on numbers of captives, only 5,000 provided numbers of captives embarked. To summarize these points, we must distinguish the proportion of voyages recorded from the proportion of captives recorded. This distinction will be utilized in the analysis below.

Important as these voyage-based data are, it is to be emphasized that many important data on slave trade and slavery stem from data organized in other ways. Curtin's 1969 census, for instance, while it relied principally on voyage-based data, used several other techniques for assembling his aggregate estimate of the volume of the slave trade. Such other data included censuses of slave populations; sales, tax, and registration records; individual records of mortality and birth; prices and values of slaves as individuals or in groups. The full history of slavery and slave trade, reliant though it is on voyage-based data, requires linking these voyage-based data to other sorts of data.[52]

Proportions of voyages and captives documented. The compilers of the 1999 slave trade dataset, in their introduction, offered estimates of what portion of the total trade was reflected in the dataset, based on comparison of the dataset to overall estimates of the volume of slave trade as given in the literature. These estimates, while revealing and helpful, were necessarily speculative, since to create them they had to assume the total size of the trade—the very figure one sought to estimate. The compilers sought to present a simplified statement on this complex issue by suggesting that the dataset included 70% of the total number of voyages.[53] In a sense, the dataset was thus argued to be broadly representative of the slave trade as a whole.

The data in this dataset tended to reaffirm the existing scholarly consensus on the volume of the Atlantic slave trade: that is, a cumulative total of perhaps 12 million people sent from Africa, or 10.5 million people arriving in the Americas. In fact, however, there was no way simply to add up columns and get such a result from this dataset: it did not yield a direct estimate of the volume of the slave trade. Instead, the data, now available in larger quantity and in more

[52] This is one of the concerns raised by Manning at a 1992 meeting at Harvard University at which plans for applying for funding of the project were formalized. The concern was in particular about price data for captives and slaves on both sides of the Atlantic, and how to preserve any such data and use them to develop a fuller analysis of the economics of slave trade. The compilers did not find a way to include price data in this dataset. (PM)

[53] The compilers, in the introduction to the CD-ROM, assert that the database documents about 70% of the captives and 70% of the voyages, by comparison to the widely recognized estimate of some 10 million captives disembarked in the Americas. This estimate is presumably made based on a projection much like that I presented in Table [3], in which average numbers of captives per voyage (based on captives totaling about 4 million in number) are multiplied by known numbers of voyages to yield a total of about 7 million captives and hence 70% of the captives and 70% of the voyages. The reasoning is necessarily circular: it assumes that current estimates represent the actual total, compares these totals with tallies based on the database, then calculates a percent covered. (In addition, the tallies based on the database mix cases of voyages where captives on board are explicitly numbered in the documents with a nearly equal number of cases where they are not.) Despite this difficulty, essentially the same technique is used for estimates in later sections of this essay.

comprehensive and consistent form, still needed to be combined with a range of assumptions in order to yield an estimate of the volume of the slave trade.[54]

The task of estimating the volume of the slave trade was, then, to compare the new version of the data in various categories to previous versions; to review the assumptions on how to estimate missing data; and to combine these into overall estimates, emphasizing distinctions among the projected origins, carriers, or destinations of captives, or of the time period in which they were carried.

The publication of the 1999 dataset in CD-ROM form brought widespread satisfaction with the advance in research materials but also brought reaffirmation of concerns about missing data. Indeed, in the following years researchers located many more records of voyages, and the compilers developed a new version, published in 2008 (and revised again in 2010) on a web platform that was far more user-friendly as a result of the development in technology in the intervening years.

Tables 2.9 through 2.16 display comparisons in the total numbers of voyages and captives reported in the 1999 and 2010 versions of the trans-Atlantic slave trade dataset. Tables 2.9 through 2.11 show that the largest *number* of additional slaving voyages was identified for the eighteenth century. But the *proportion* of added voyages was greatest for the sixteenth and seventeenth centuries. Thus the new data for the eighteenth and nineteenth centuries did most to increase the estimated overall volume of the slave trade. On the other hand, the new data collected for the sixteenth and seventeenth centuries did most to show how significant transatlantic slave trade had been for almost four hundred years.

Initial debate and numerous publications relied on the 1999 CD-ROM. Thus, although the 2010 version of the dataset is the most updated and the most reliable, the 1999 version was the basis for the analysis and interpretation of publications appearing from that time for the succeeding decade. Details of the 1999 version and comparison of its results with those of the 2010 version remain important overall.

Tables 2.9, 2.10, and 2.11 compare the results of the 1999 dataset and the 2011 dataset to show how much additional data was collected in the decade after the first release of the dataset. At the same time, these tables provide information on the distinction between the most basic available information—the number of voyages, their timing, and their trajectory—and the information of greatest historical interest, on the numbers and characteristics of the captives transported in these voyages. As is indicated in these three chapters, we have specific indications on the number of captives on some 25% of the voyages, and we have additional detail on the age and sex composition of captives for roughly 10% of the voyages.

Tables 2.12 through 2.16 explore the "imputed" variables of the 1999 dataset and the 2010 dataset. On the basis of the primary evidence collected within each of the datasets, Eltis and his colleagues created "imputed" estimates of the missing data. In addition, based on these results – greatly expanded in comprehensiveness from previous collections of data—Eltis and his

[54] For the approach that David Eltis adopted in projecting estimates of captives carried from data on the number of voyages, see Eltis 1979.

colleagues published books and articles giving their interpretation of the data as regards the demography and economics of the slave trade itself, the impact of slave trade on the Americas, and the impact of slave trade on Africa. The details of the 1999 dataset and 2010 data set are discussed in the remainder of this chapter; the analyses published by Eltis and others are discussed in Chapter 3.

Table 2.9. Slaving Voyages, 1999 and 2010 totals.
Source: 1999 and 2010 datasets.

Century	1999 Voyages	2010 Voyages	Difference	% increase
1500s	155	224	59	38
1600s	1,707	2,903	1,196	70
1700s	16,768	20,706	3,938	23
1800s	7,130	9,585	2,455	34
Total	**25,760**	**33,418**	**7,648**	**30**

Tables 2.10 and 2.11 show the total number of reported captive embarkations and disembarkations, by century, in the 1999 and 2010 datasets, as given in the summary variable for each. These tables were developed from the data given for each of the voyages, but also from additional data enabling the compilers of the dataset to attribute numbers of captives embarked and disembarked for individual slave voyages.[55] Of the number of captives reported in each cell, the compilers found it possible to retrieve some sort of information on the age and sex of roughly a quarter of them.[56] As is clear from Tables 2.10 and 2.11, the number of captives documented while embarking was significantly and consistently smaller than the number documented while disembarking.

Table 2.10 Recorded Captives Embarked, 1999 and 2010 totals.
Source: 1999 and 2010 datasets.

Century	1999 Embarked	2010 Embarked	Difference	% increase
1500s	1,323	15,608	14,285	92%
1600s	97,782	174,592	76,810	44%
1700s	1,116,554	1,439,182	322,628	22%
1800s	953,667	1,103,326	149,659	14%
Total	2,169,326	2,732,708	563, 382	21%

[55] That is, summing the total number of captives reported for all of the voyages for any cell will give a smaller number than that reported in the cell; the compilers have used other techniques where they believed that these techniques gave accurate numbers of captives for individual voyages.

[56] For the 1999 version of the dataset, recorded captives embarked for which there were data on age and sex included 645,932 out of 2,219,327 (29%); recorded captives disembarked for which there were data on age and sex included 1,159,546 out of 4,280,820 (27%). For the 2010 version of the dataset, recorded captives embarked for which there were data on age and sex included 681,442 out of 2,732,646 (25%); recorded captives disembarked for which there were data on age and sex included 846,231 out of 5,043,896 (16%).

Table 2.11. Recorded Captives Disembarked, 1999 and 2010 totals.
Source: 1999 and 2010 datasets.

Century	1999 Disembarked	2010 Disembarked	Difference	% increase
1500s	24,906	42,665	17,759	42%
1600s	219,335	272,843	53,508	20%
1700s	2,277,162	2,744,308	467,146	17%
1800s	1,759,397	1,984,080	224,683	11%
Total	4,280,800	5,043,896	763,096	15%

Most recorded captives were noted simply as numbers of persons, without further description. In a minority of the cases—perhaps 10% of the voyages with information on captives—further data were given on age and sex of captives. Thus, of 5.0 million captives recorded as having been disembarked in the 2010 dataset, there were records on both age and sex for 712,000 of them, or 14%.[57] Of 2.7 million captives recorded as having been embarked in the 2010 dataset, there were records on both age and sex for 240,000 of them, or 9%.[58] In addition, deaths at sea were attributed by age and sex to only 17,600 persons in the 1999 version and to 46,183 in the 2010 dataset; total deaths at sea recorded were 135,000 for the 1999 version and 164,000 for the 2010 version: these were barely 10% of the roughly 1.5 million deaths at sea that are calculated to have taken place. To summarize this range of data on transatlantic slave-trade voyages: we have some sort of data on the great majority of voyages, we have some data on roughly one fourth of captives embarked and one half of those disembarked, and we have details on age or sex for under 6% of those embarked, for about 3% of those who died at sea, and for 9% of those disembarked. The data are thus uneven—yet, as we will show, it is possible to develop relatively dependable estimates from these figures for the overall pattern of captive migration, including their distribution by region, age, and sex.

Comparison of the 1999 dataset and the 2010 dataset gives some hints as to the amount of additional data that may ultimately be collected. For the eighteenth century, the best-documented period because slavery was legal and had become highly capitalized, the additional ten years of research brought an additional 23% of voyages and an additional 17% of imputed disembarkations. This suggests that the voyages added to the dataset were of smaller-than-average vessels, and that the number of additional voyages to be found, while significant, is not immense. For the nineteenth century, from 1999 to 2010 the number of recorded voyages increased by 34% but the number of imputed disembarkations increased by only 11%--again suggesting that the added voyages were of smaller-than-average vessels, but that a significant number of additional voyages and captives are yet to be documented. For the seventeenth

[57] Adding those for whom data were recorded on just age or sex, one reaches a total of 846,000 captives or 17%.
[58] Adding those for whom data were entered on just age or six, one reaches a total of 640,000 captives or 24%. One may note that the total number of captives for whom age and or sex were recorded actually *declined* from 1.86 million to 1.57 million from the 1999 version to the 2010 version. This means that for at least 300,000 captives attributed with age or sex in 1999, it was determined by 2010 that no age or sex could dependably be attributed to them.

century, the number of recorded voyages increased by a remarkable 70%, and the number of imputed disembarkations increased by 20%. Again, the newly reported voyages were smaller than average, but it may be that there are many more to report. For the sixteenth century, the number of voyages recorded rose by 38% and the number of disembarkations rose by 42%. Apparently the newly-recorded voyages were of average-sized vessels, and the new research significantly increased the sixteenth-century proportion of the overall slave trade. In sum, the expanded research has shown that, while the number of additional captives documented was greatest for the eighteenth century, the relative size of all other time periods rose during the last campaign. One may speculate that further research will continue this pattern. Ultimately, we will confirm the eighteenth century as the greatest period of transatlantic slave trade, but we will show that the proportions of transatlantic slave trade in the earlier and later centuries were larger than previously thought.

Imputed variables. David Eltis and his colleagues took the first steps toward extrapolating the data they had compiled to give a broad quantitative picture of the Atlantic slave trade. Based on the available information on numbers of captives per voyage and on their age and sex distribution, the compilers calculated "imputed variables" with which they sought to fill in the missing data. These imputed variables were calculated with attention to the changes in the number of captives per voyage (and their mortality rate) and also with attention to variations in time, the trajectory of the voyage, and the national carrier or flag. In estimating these missing values, however, the compilers did not include an accounting of the error margins involved in moving from known values on some voyages to unknown values on a larger number of values. We return to this issue in chapters 7, 8, and especially 9.

The compilers published their imputed figures on the totals and the distribution of captive migration by time, origin, destination, and national carrier. These are summarized in Table 2.12 (for the 1999 version) and Table 2.13 (for the 2010 version).

Table. 2.12. Imputed Estimates for Captives Embarked and Disembarked, 1999 version.
Source: 1999 dataset.

Century	Embarked	Disembarked	Difference	% loss
1500s	31,754	26,834	4,920	15%
1600s	469,981	386,345	83,636	18%
1700s	4,809,033	4,078,869	730,164	15%
1800s	2,633,473	2,266,937	366,536	14%
Total	**7,944,241**	**6,758,985**	**1,185,256**	**15%**

Table 2.13. Imputed Estimates for Captives Embarked and Disembarked, 2010 version.
Source: 2010 dataset.

Century	Embarked	Disembarked	Difference	% loss
1500s	94,679	69,208	25,471	27%
1600s	908,126	712,010	196,116	22%
1700s	5,717,421	4,924,191	793,230	14%
1800s	3,427,728	3,047,588	380,140	11%

Total	**10,147,954**	**8,752,997**	**1,394,957**	**14%**

While the details of the methodological description show clearly the way in which these estimates were calculated from the basic data, many readers have gained the impression that these imputed totals were calculated directly from the data. While the imputed totals are clearly a sensible approximation, their calculation does not represent the only way to go from the original data to estimates of overall flows of translatlantic slave trade.

Meanwhile, well before the design and creation of the 1999 dataset, Paul Lovejoy published a 1982 update of Curtin's 1969 estimates, providing aggregate estimates of captive migrants embarked on the African coast by region and national carrier, to account for the advances in the literature to that point. In total, Lovejoy estimated that a total of 11.7 million Africans were embarked on transatlantic slave ships. The 1999 dataset could thus be compared with the Lovejoy estimates to get a sense of the relative completeness of the voyage-based approach. The result, as suggested by Eltis et al., was that the 1999 dataset was able to account for roughly 70% of all slaving voyages and also for 70% of the transatlantic captives. Indeed, as shown just below, by comparing this estimate to an existing estimate of the total -- for instance, the 1982 estimate of Lovejoy -- we find that the 1999 dataset accounts for just over 70% of the total in the estimate.

Table 2.14. Lovejoy estimate vs. imputed totals from Eltis 1999 and Eltis 2010
Source: Lovejoy (1982) and Eltis et al. (1999) [59]

	Lovejoy (embarked)	85% of Lovejoy (disembarked)	1999 dataset (disembarked)	2010 dataset (disembarked)
to 1600	367,000	312,000	26,834	69,208
1600s	1,868,000	1,588,000	386.345	712,010
1700s	6,133,000	5,213,000	4,078,869	4,924,191
1800s	3,330,000	2,805,000	2,266,937	3,047,588
Total	11,698,000	9,918,000	6,758,985	8,752,997

The comparison of Lovejoy and Eltis results is best made for the captives disembarked, since the 1999 dataset includes better data for disembarkation than for embarkation. Since Lovejoy's estimates were for captives embarked, one needs to use an estimated rate of mortality to convert them into estimates of captives disembarked: column 3 in Table 2.14 shows an estimate of 9.9 million captives disembarked in the Americas. Indeed, the 1999 Eltis estimate of total captives disembarked (column 4) is just under 70% of the revised Lovejoy estimate (column 3). On the other hand, for the eighteenth century, the projected totals from the dataset reach 88% of the Lovejoy estimates for slave imports to the Americas. In addition, for two national carriers, the English and the Dutch, these projected totals from the 1999 dataset exceeded the Lovejoy estimates (Table 2.15). These comparisons indicate that the 1999 dataset was an impressively

[59] see also Lovejoy 1989.

substantial but still not representative portion of all the slaving voyages. (Further work made a difference: remarkably, the revisions in the 2010 version of the dataset came out to be almost identical to 85% of the Lovejoy estimate.)

Conducting the same comparison of Lovejoy and Eltis et al. figures for captives carried by flag or national carrier brings another interesting result. Table 2.15 shows that the 1999 dataset's imputed totals of numbers disembarked by flag (4.4 million) were 85% of the Lovejoy totals disembarked by flag, so that this calculation made it appear that the 1999 dataset figures were more complete than appeared by looking at captive totals (Table 2.14). On the other hand, Table 2.15 also shows that when the revised Eltis et al. figures were released in 2010, they showed smaller rather than larger totals for captives disembarked under English, Portuguese, French, and Dutch flags—that is, some of the earlier captive estimates had been too high or had been attributed to the wrong national carrier. A further point was that the 2010 estimate of total disembarked by flag (5.6 million) exceeded the Lovejoy-based estimate of 5.2 million. This higher total suggests that the additional data collected after 1999 consisted not only of the details of voyages carrying known numbers of captives, but also that the number of captives (and voyages) was larger than had been earlier thought.

Table 2.15. Captive totals by flag, 1701-1800: Lovejoy vs. Eltis 1999 and Eltis 2010

	Lovejoy (embarked)	85% of Lovejoy (disembarked)	1999 dataset (disembarked)	2010 dataset (disembarked)
English	2,532,000	2,152,000	2,203,000	2,150,334
Port	1,796,000	1,527,000	767,000	1,991,362
French	1,180,000	1,003,000	964,000	959,170
Dutch	351,000	298,000	323,000	286,802
N Am	194,000	165,000	120,000	157,337
Danes	74,000	63,000	37,000	55,628
Spain				9,235
Total	6,127,000	5,208,000	4,414,000	5,609,869

The imputed totals of captives embarked in Africa for the Atlantic slave trade, as calculated by the Eltis team, are shown in Tables 2.16 and 2.17. They are shown by century and by African region of embarkation, along with (for Table 2.16) the number of voyages identified for each region and century. The voyages reflect direct coding of original data, though the documentation on some voyages is very scant. The captive totals, in contrast, have been developed based partly on original data but mostly based on estimates of the number of captives per vessel on each voyage. These figures have been carefully reviewed and doubtless represent the broad outlines of the Atlantic slave trade.

Table 2.16. Imputed Embarkations, by African Region

Source: 2010 dataset

Columns give the names and numbers of African regions in the dataset. Rows are organized by century (1500 = 16th century, etc.); Voy = number of voyages in category; Cap = number of captives boarded. (Voyages: majbyimp by year100; **Captives: ___ by** year100.)[60]

Slaves boarded by African region, by century

		1	2	7	3	4	5	6	8	
Date	Var	Sen	S.L.	Wind	GC	Benin	Biafra	WC Af	SE Af	Tot
1500	Voy	189	3	0	0	0	25	71	0	300
1500	Cap	147,281	1405	2492	0	0	8,459	117,878	0	277,506
1600	Voy	335	22	3	181	546	362	972	52	2,644
1600	Cap	136,104	6,843	1,350	108,679	269,812	18,322	1,134,807	31,715	1,875,631
1700	Voy	1,501	722	791	2,406	3,214	2,324	4,290	169	16,426
1700	Cap	363,187	201,985	289,583	1,014,529	1,284,585	904,616	2,365,204	70,930	6,494,619
1800	Voy	314	363	118	242	869	956	3,560	690	7,277
1800	Cap	108,941	178,537	43,454	86,114	444,662	495,164	2,076,685	440,022	3,873,580
Total	Voy	2,339	1,110	912	2,829	4,629	3,667	8,893	911	26,647
	Cap	755,513	388,771	336.868	1,209,321	1,999,060	1,594,590	5,694,574	542,668	12,521,336

Conclusion: Incremental advances in knowledge

This chapter has reviewed the data and analysis developed to the present on the size of African population and on the size and direction of African migration. In sum, the work assembled in documenting African population and African migration shows the value of the vision—first laid out with clarity by John C. Caldwell in his 1985 chapter in the UNESCO *General History of Africa*—of a comprehensive scholarly picture of historical African population (Caldwell 1985). This vision of an integrated and systematic picture of African population over time, as it comes into being, will replace the previous guesswork, inconsistency, and sheer neglect of the connected past and present of African demography.

The developing knowledge of African demographic history has taken form not through spectacular empirical discoveries, astounding insights, or sudden interconnections. Indeed, most of the developments have taken place in segmented subfields, which have emerged and combined only incrementally with each other. No one set of data, no one theoretical approach, is determinative in providing an overall picture of the evolution of African systems of population and migration. Over the past half-century—since African nations gained political independence

[60] Note that the right-hand column, on totals, includes additional known voyages and captives that could not be allocated among specific African regions.

from colonial rule—knowledge has advanced in every arena of African population studies, though more in some than in others.

For population since 1950, we have systematic and detailed surveys and censuses of most regions of the continent. For the demographic records compiled during the colonial period, roughly seventy years in length, we have since learned of their flaws, most commonly their substantial underestimates of population sizes. Nevertheless, these same records, when analyzed with the same techniques and energy that United Nations demographers have applied to post-independence censuses and surveys, can surely provide valuable evidence on colonial-era demography. For population in the precolonial era, we have yet to get definitively beyond the long era of wild and undocumented guesses. Nevertheless, the circle is closing: as population historians collect additional information on African migration patterns and vital rates, and as comparisons with the population history of other regions becomes more detailed, there will be a basis for estimate of historical African populations relying on evidence and not just speculation.

For migration, similarly, the knowledge base has expanded substantially. Migration within and among African countries in the era since independence, while rarely documented in detail by African governments, has been traced in considerable detail by international organizations. Postcolonial data can be mined, with the help of international organizations where national governments have fallen short in record keeping. This will combine tracing economic migrants, political refugees, and others, and will bring us the benefits of comparing and combining the regionally and temporally segmented stories. Similarly, for the colonial period, a great deal of information on migration remains to be assembled and put in contact with the larger history of African migration. Labor migrations were documented by governments and scholars, especially from the 1930s forward; police and military records provide information on colonial-era refugee movements. For the precolonial era, by far the most detailed and systematic data address the transatlantic slave trade. For all their detail and significance, these data are still seriously incomplete. Research has already begun to extend the value of these data by estimating missing data and by exploring the implications of these data for associated issues in history of the Atlantic, Africa, and the Americas. Continuing research in recent years has brought substantial improvement in slave-trade data on the Indian Ocean Area; a more gradual advance is bringing additional data on North Africa and Red Sea regions.

The single biggest tabulation of migration data is the Slave Voyages dataset, backed by the immense wave of research that gathered its content. The greatest strength of the dataset is for the late eighteenth century, a period for which it seems to have documented securely the volume and composition of the Atlantic slave trade in the era of its maximum volume -- a peak of 300 recorded voyages per year, with 80,000 captives landed from those ships in the Americas.[61] The dataset also provides very strong documentation on the Atlantic slave trade during the nineteenth century. For most segments of the trade, the dataset appears to confirm the order of magnitude previously advanced by these and other scholars for those parts of the trade that are well documented. While the dataset needs to be treated critically and at times skeptically, and while we should be cautious in using the dataset to affirm the truth of a given figure or historical

[61] To these totals ought to be added those of the undocumented slave trade of the era, especially that in Portuguese and Brazilian vessels. These would not come to another 30% in this well-documented era, but might come to another 10%.

interpretation, its overall strength is evident. The claims of David Henige that the effort of quantification is a waste of time, both for estimating the volume of the Atlantic slave trade and the size of precontact Amerindian poplations, may have a certain heuristic utility.(Henige 1986, Henige 1998) But demonstrably, for the Atlantic slave trade, these data are of substantial use for reconstructing the social and demographic history of this immense forced migration.

While the 2010 online version of the dataset is the most authoritative, the 1999 version remains important. Numerous publications analyzing the nature and implications of Atlantic slave trade relied on the 1999 CD-ROM. The initial version is the basis for the analysis and interpretation of publications appearing from that time for the succeeding decade. Chapter 3 gives of this volume includes a review of that work. The 2010 dataset gives significantly expanded results, the analysis of which is only beginning to appear. This work will include the age and sex composition of cargoes, mortality rates, the variations in volume of slave trade at individual African and American ports, and details on the crews and owners of ships.

As for the present volume, to the degree that it reflects an advance in clarifying African demographic history, it is because of emphasis on two methodological approaches. First of these is the approach of systematic linkage of historical patterns across space, time, and topic, which has arisen especially in recent studies of world history. Second is the focus on demographic patterns and theory, including statistical theory—relationships that are often basic but for which systematic attention often yields significant results. Systematically asking demographic questions in a connected and world-historical context is the basis of the chapters to come.

In later chapters of this book we show that, using additional statistical techniques, it is possible to use the existing data from the 2010 dataset and develop considerably more detailed estimates on the points of origin and destination of captives and their distribution by age and sex (for embarkation, death at sea, and disembarkation). On the other hand, we also take on a related but quite different task, especially in Chapter 6: that of documenting and estimating migration within precolonial Africa, especially through enslavement.

For the precolonial era, still other types of work remains to be expanded, building on the achievements of the Slave Voyages data collection: this can take the form of constructing collateral datasets which can be linked, directly or indirectly, to the Slave Voyages dataset. These will be of several types. One type consists of attempts to fill in the gaps in shipping data with other methods of estimating of transatlantic migration of captives, as with Curtin's early projections of migration to Cuba and Puerto Rico from census counts of Caribbean slave population.(Curtin 1969, Manning, 1990) A second consists of estimates of the further migration of slaves in the Americas, such as those dispatched from Jamaica to Cartagena and beyond, or those moved from Northeast Brazil to Southern Brazil in the nineteenth century. Finally, there is the strong tradition of studies of slave communities in the Americas, ranging from Frederick Bowser's work of the 1960s on Peru to David Geggus's study of slaves in Saint-Domingue.(Bowser 1973, Geggus, 1989) Indeed, work is now expanding on slave communities and maroon communities in Africa.

Chapter 3

Population as Affected by Slave Trade: Previous Estimates

West and Central Africa
North, Northeast, and East Africa
Conclusion

Slave trade and its impact on African population, two distinct but tightly interlinked issues, have together received more attention than any other topic in the demographic history of precolonial Africa.[62] The literature on the African demographic impact of slave trade grew up after that on the slave trade itself, and has been reviewed less fully.[63] This literature is derivative from that on export slave trade, to the degree that slave export figures are the basis of most projections of African demographic impact. But it is also a distinct field of inquiry, in that the assessment of African demographic impact requires data and analysis on fertility, mortality, migration patterns, and population size within Africa in addition to the character of export slave trade.

Since the days of Malthus, demographers and students of Africa have sought to assess the impact of slavery on African demography. Malthus, writing as an opponent of slave trade, acknowledged that slave trade removed many Africans from the continent, but he emphasized the regenerative power of African populations.

> Notwithstanding this constant emigration, the loss of numbers from incessant war, and the checks to increase from vice and other causes, it appears that the population is continually pressing against the limits of the means of subsistence.(Malthus (1817), I:208)

But Malthus, basing his views on no more than a few travelers' narratives, was working in a virtual absence of data. His attempt was to assess the population of an African "black box," as influenced by a large yet unmeasured emigration of slaves.

The range of interpretations of Malthus's contemporaries and successors underlines the difficulty of knowing how slave trade influenced African population. Their conclusions were vague, speculative, or both. Pro-slavery propagandists such as English merchant and historian

[62] An earlier version of this chapter was accepted for publication but not actually published in *Annales de demographic historique*, in [1990]. For a review of the quantitative literature on the Atlantic slave trade, see Lovejoy 1982. On the earlier literature on the volume of slave trade, see Curtin 1969. See also Rawley 1981 and Inikori 1982.

[63] The most comprehensive statement on the demography of African slavery remains Manning 1981. See also Caldwell 1985, Thornton 1982, Lovejoy 1983, Manning 1983, Manning 1990b, and Henige 1986.

Archibald Dalzel argued that the impact of slavery on African population was negligible, since the exported captives would otherwise have been executed in Africa.(Archibald Dalzel 1793) Thomas Clarkson, the leading propagandist of the successful campaign for British abolition of slave trade, was concerned more with the barbarity induced by slave trade than with depopulation of Africa, but his disciple Thomas Fowell Buxton, in a book supporting his Parliamentary proposal for a further campaign against slavery, estimated that Africa had suffered severe depopulation because of the mortality brought by slave trade.(Clarkson 1968, Buxton 1839) David Livingstone, the famed missionary-explorer, tended to confirm Buxton's impression in the course of his observation of the East African slave trade in the third quarter of the nineteenth century.(Livingstone 1866) At the turn of the twentieth century H. H. Johnston, a British adventurer, imperial official, and historian, conceded the demographic impact of slavery to have been negative, but thought this negative impact was counterbalanced by the benefits of European culture for Africa.(Johnston 1899) A. M. Carr-Saunders, in his 1936 survey of world population, estimated that the losses of slave trade held African population at a steady one hundred million from 1500 to 1700, with a decline to ninety million in 1800, while the populations of the other continents grew. All these arguments, however, were built on a data base little expanded from that available to Malthus.(Carr-Saunders 1936; Willcox 1931)

West and Central Africa

Interest in African demographic history expanded along with studies of the volume of slave trade in the 1970s. Data became more plentiful and issues clarified, with the result that a series of debates took form. The issues included not only African patterns of fertility and mortality, but the migration entailed in slave trade, through which the population and economy of Africa were linked indissolubly with the wider Atlantic the Atlantic slave trade and on New World slavery. The result of this research and debate was to improve greatly the picture of the size and structure of the emigrating African population, both in transit and on arrival. As a result of this research, one may say that there was a known flow of captives from the African black box.

Further data came from recent empirical work on African historical demography. Detailed studies for certain regions and certain time periods provided insights into African patterns of fertility, mortality, and migration in the era of slave trade.(Curtin 1975, Cooper 1978, Northrup 1978, Manning 1982, Miller 1998, Cordell 1985) When combined with the far more extensive work in African political and economic history, these insights could be extended.[64] To pursue the metaphor, let us say that we can now peer into sections of the black box, and that the previously complete obscurity is increasingly relieved by patches of gray.

But the new data were not sufficient to overcome some great speculative gaps, nor to resolve the basic issues of the size, structure, and growth of African population in the era of slave trade. Thus John C. Caldwell argued that the sixteenth-century population of the western coast of Africa was small and that it grew rapidly, overcoming the losses from captive exports, while Louise-Marie Diop-Maes argued that the same population was relatively large and that it was reduced by captive exports.(Caldwell 1978, Diop-Maes 1985) Joseph C. Miller argued that the

[64] For example, Kea (1982) gives great detail on the location and dize of towns, occupational structure, and political structure for Gold Coast, which can be linked to demographic issues.

population of Angola, the region contributing more captives to the New World than any other, did not decline despite captive exports, while John D. Fage argued that it did decline. Fage concluded that the impact of captive exports in West Africa was small, while John Thornton argued that both there and in Central Africa the population structure was transformed, especially through change in the sex ratio.(Miller 1982, Fage 1975, Fage 1969,Thornton 1982)

Manning, in a 1981qualitative model of the effects of African enslavement in sub-Saharan Africa, the Americas, and the Old World Diaspora, sought to encompass the full range of issues in the demographic impact of slave trade. In conclusion, he argued for serious loss of population to enslavement and therefore for higher populations in earlier times. Caldwell, in his response to Manning, conceded in part that this analysis should bring revision to his earlier assertion (in the UNESCO General History, which was published only in 1985) that small African populations had grown rapidly before and during the era of slave trade.(Manning 1981; Caldwell 1982, Caldwell 1985) Manning's 1990 book brought forth specific assertions of declines in African populations and dramatic distortions of the adult sex ratio in many African regions, but the discussion on African demographic change then declined for a time.(Manning 1990)

The debates over the demographic impact of slave trade thus combined a welter of interconnected issues, which must be distinguished from each other and resolved one at a time in order to solve the whole puzzle of the impact of slavery on African demography. The issues include the following:

1. **Volume of the Atlantic slave trade** - including its timing, its age and sex composition, and the mortality in the Middle Passage.
2. **Volume of the Old World export slave trade** - The size of the export slave trade across the Sahara, the Red Sea, and the Indian Ocean, including its timing, its age and sex composition, and mortality in the course of transit across desert and sea.
3. **Magnitude of African population** - The size (and the regional distribution) of the African population before and during the slave trade.
4. **The "loss/emigration ratio"** – that is, the short-run decline in African population resulting from the export of a single captive. This can be estimated in crude terms (neglecting fertility) or in net terms (including the children born to women in Africa within this short-run period).
5. **African levels of fertility and mortality** in the slave-trade era, and any changes these may have undergone as a result of slave trade.
6. **Age and sex composition of African populations** - The impact of captive exports on the age and sex composition of African populations.
7. **Hardest hit regions** - The determination of which African regions lost the largest number of captive emigrants.
8. **African growth or decline** - The net growth or decline of African population over time as a result of slave trade.
9. **Regional variation** - Variations by region and over time of the factors listed above.
10. **Continental enslavement** - The magnitude and demographic effects of enslavement within sub-Saharan Africa.

11. **Counterfactual population** - Finally, the counterfactual population that Africa would have had in the absence of slave trade.

1. **Volume of the Atlantic slave trade.** The volume of the Atlantic slave trade has occasioned the greatest debate of all of these. Curtin's initial cumulative total of roughly ten million New World disembarkations was challenged and increased in a number of areas, but the net result has been to change the consensus only slightly; Joseph Inikori retained his belief, however, that the total was closer to fifteen million embarkations.(Inikori 1982) Part of the difference between these two figures is Middle Passage mortality of 1.5 to 2 million captives over three centuries. (It should be noted that these cumulative totals are statistics without any time dimension, and they fit uneasily at best into demographic calculations since they cannot be expressed as an incidence or be related to a clear population at risk.)

2. **Volume of the Old World export slave trade.** The volume of the Saharan, Red Sea, and Indian Ocean trades has undergone far less study. Ralph Austen attempted the most serious global estimates of these trades; the margin of error is necessarily much higher than for the Atlantic trade because of the nature of the sources.(Austen 1979a, 1979b, 2010) The result of Austen's work is to suggest that these Oriental trades went on at a low level over a long time, so that the cumulative total of captive exports is roughly comparable to that of the more compressed Atlantic slave trade. At the same time, Austen's work and that of other authors makes clear that the nineteenth century was the time of most intensive export of captives to the north and east.[65]

3. **Magnitude of African population.** Several authors have speculated briefly on the size of African population before captive exports grew to a high level, but John C. Caldwell did so most systematically.(Caldwell 1978, 1985)[66] His conclusions, stated most firmly for the West African coast, were that the African population was relatively small, as a result of the recent occupation of the forest and the low productivity of available foodstuffs. This viewpoint leads logically to the conclusion that African population grew during the era of captive exports. Caldwell was challenged on this issue by Inikori and Manning, and Manning in turn was challenged in detail for the case of the Bight of Benin by Wigboldus.(Inikori 1982, Manning 1981, Manning 1982, Wigboldus 1985)

4. **The "loss/emigration ratio."** The debate over the "loss/emigration ratio" has yet to become explicit, but the authors involved in the debate over slavery and African population have implicitly assumed widely different values for this ratio. Here we define this ratio and some related ratios in an effort to lend more precision to the discussion, and then discuss estimates of various authors.

Three variables are involved in the calculation of the relevant ratios: the number of emigrants or captives departing an African region within a given time period, the size of the regional population at a given time, and the loss of African population through emigration plus the associated mortality within Africa (e.g., battle casualties, mortality on the march to the

[65] Add Campbell, Sheriff, Allen, etc.

[66] Caldwell (1985) was written roughly a decade before it was published (such have been the exigencies of the UNESCO *General History of Africa*), and therefore does not include references to work after 1975. See also Caldwell (1982).

coast). The latter variable may be interpreted in at least two ways: as "simple loss," the number of captive emigrants plus direct slavery-related mortality; or as "net loss," including fertility and other mortality. Net loss is the most crucial variable for assessing African population growth or decline, both in the short run and in the long run: in the short run because crude birth rates were affected by the age and sex composition of the emigrants; in the long run because both fertility and mortality patterns may have been affected by slavery. There exists no straightforward relationship between simple and net loss: net loss should normally be smaller than simple loss because of fertility, but the reverse is true for a naturally declining population.

The variables involved in calculating the relevant ratios are displayed schematically in Figure 1. They include the initial African population A, normal mortality B, captive emigration C, additional mortality due to enslavement D, survivors after enslavement E, births after enslavement F, and additional births that would have occurred without enslavement G.[67]

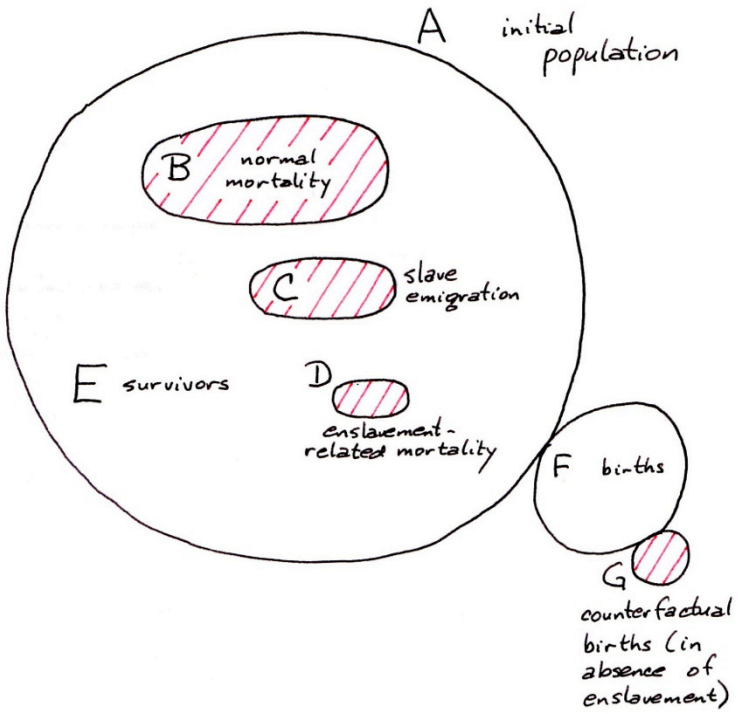


Figure 1. An African Population after an Episode of Enslavement.

[67] The initial population A = B + C + D + E. The resultant population without enslavement equals A – B + F + G; the resultant population with enslavement equals E + F = A – B – C – D + F. Births may be assumed to be a complex function of the other variables.

Table 3.1. Rates of Population Growth and Loss to Enslavement, as Calculated by Various Authors.[68] (NB: Definitions have been adjusted so that negative signs indicate decline in African population.)

		Fage	Buxton	Thorn-ton	Cald-well	Man-ning
		1969	1839	1980	1985	1986
Normal growth rate (per thousand initial pop)	$\frac{-B+F+G}{A}$	1.6		2.0	3.5	5.0
Rate of captive emigration (per thousand initial pop)	$\frac{-C}{A}$	-1.6	-2.4	-2.7	-2.8	-2.8
Rate of loss to Enslavement (per thousand initial pop)	$\frac{-C-D}{A}$	-1.6	-4.8	-2.7	-3.5	-3.7
Implicit growth rate Under enslavement (per thousand initial pop)	$\frac{-B+F}{A}$	1.6		2.0	3.5	3.3
Net growth rate Under enslavement (per thousand initial pop)	$\frac{-B-C-D+F}{A}$	0.0		-1.4	-0.1	-2.4
Simple loss/emigration Ratio (per captive exported)	$\frac{-C-D}{C}$	-1.0	-2.0	-1.0	-1.3	-1.4
Net loss/emigration Ratio (per captive exported)	$\frac{-B-C-D+F}{C}$	0.0		-0.26	-0.05	-0.22

John D. Fage estimated an average eighteenth-century West African rate of captive emigration of 1.6 per thousand per year and, implicitly, a rate of loss to enslavement of 1.6 thousand as well.(Fage 1969) He assumed the minimal simple loss/emigrant ratio of 1.0: the exported captive is the only person lost as a result of slave trade. Finally, since he estimated the growth rate under enslavement remained at 1.6 per thousand, he concluded that the net loss and the net growth rate under enslavement were zero.

At the other extreme, Buxton assumed high totals for captive emigration and an 1840 African population of about 100 million, which yields a captive emigration rate of 2.4 per thousand, calculated for the continent as a whole. His estimate of the rate of loss to population rose to 4.8 per thousand. He assumed that half of all captives died before embarkation on slave ships, which corresponds to a simple loss/emigrant ratio of 2.0. Buxton did not estimate net loss/emigrant ratios or rates of net African population change.(Buxton 1840)

[68] Sources: Fage (1969); Buxton (18390; Thornton (1980) - the figures displayed are those which he says represent the break-even point for population growth; Caldwell (1985) – the figures displayed are the means of the range he gives for the eighteenth century; Manning (1985).

Thornton estimated a break-even point: the flow of captive emigrants that African regions could provide with a decline of no more than 7% in the regional population over a century.(Thornton 1981) He assumed a low normal growth rate of 2 per thousand. On the other hand, he assumed no enslavement-related mortality with Africa (though he noted that assumption to be optimistic). Thornton's "break-even point" thus assumes a net growth rate under enslavement of 1.4 per thousand. At that level of enslavement, the export of four captives would cause the African population to decline on net by one person (this result is obtained by inverting the net loss/emigration ratio). Thornton concluded, however, that no African region except Angola had rates of captive export high enough to cause declining population. Thornton's work on the Angolan censuses of 1777 and 1778 provides data on a region of intensive slave trade.(Thornton 1980) His calculations (not shown in Table 3.1) yield a rate of captive emigration of roughly 32 per thousand. He does not estimate slavery-related mortality, but his estimates of net loss imply a growth rate under enslavement of 26 per thousand, a net growth rate under enslavement of -6 per thousand, and a net loss/emigration ratio of 0.19, or a decline of one in African population for every five captives exported.

Caldwell's estimates for the western coast of Africa suggest a rate of captive emigration of from 2.5 to 3.1 per thousand during the eighteenth century, and a rate of loss to enslavement of from 2.9 to 4.2 per thousand. Assuming net natural rates of increase of 3 or 4 per thousand, Caldwell concluded that population growth was likely to have been halted for the region as a whole, and that population was certain to have declined in Angola during the eighteenth and nineteenth centuries. Caldwell assumed simple loss/emigrant ratios of 2 for the sixteenth and seventeenth centuries, 1.3 for the eighteenth century, and 1.2 for the nineteenth century. Joseph Inikori assumed a simple loss/emigrant ratio of 1.5. Caldwell's calculations suggest a decline of one in African population for each twenty captives exported.(Caldwell 1985, Inikori 1982)

Manning, in work based on computer simulation, calculated estimates for each of these ratios, for the western coast of Africa during the eighteenth century.[69] These results include a rate of captive emigration of 2.8 per thousand, a rate of loss to enslavement of 3.7 per thousand, and a net growth rate under enslavement of -0.4 per thousand (that is, a slightly declining population). These figures correspond to a simple loss/emigrant ratio of -1.4, and a net loss/emigrant ratio of -0.22. The last ratio, when inverted, implies that for every five captives exported, African population declined by one person, even accounting for natural population increase. These simulation calculations include another important and apparently paradoxical result: the African population began with a net natural increase of 5 per thousand, and yet a smaller simple loss/population ratio of 3.7 per thousand was sufficient to cause population decline. The resolution of the paradox lies in the distortion of the African age structure; the female captives exported, even though they were only half the number of males exported, were sufficiently concentrated in the young adult years that their disappearance caused the implicit growth rate under enslavement (or the adjusted rate of net natural increase) to fall to 3.3 per thousand.(Manning 1985)

The net loss/emigrant ratio is the most crucial measure for the assessment of long-term African population growth or decline, and it depends on the age and sex composition of the exported captive composition. The fact that women were left preferentially in Africa gave them a

[69] Manning (1985). See Chapter 1 for an introductory statement on this point.

chance to reproduce; but the fact that the preponderance of women exported were young adults threatened the population's ability to reproduce. [stages 1969, 1981, 2000?]

5. **African levels of fertility and mortality.** African levels of fertility and mortality are important to the determination of whether population could have grown despite the losses of captive trade. Caldwell proposed, as a "medium assumption," an expectation of life at birth of 22.5 years, crude birth rate of 48 per thousand, crude death rate of 45 per thousand, and an infant mortality rate of 300-350 per thousand.(Caldwell 1985) This would yield a net rate of natural increase of 3 per thousand. Thornton studied a baptismal register from eighteenth-century Kongo, and concluded that expectation of life at birth was 27.5 years, fertility was 48 per thousand, and mortality was 38 per thousand, which yields a net rate of natural increase of 10 per thousand.(Thornton 1978) The two authors agreed on a high birth rate and high death rate, but the differences between them are large enough to allow for conflicting hypotheses about net population growth rates. In a later study, Thornton argued that, despite potential for rapid growth in the short run, African population growth over the long run was closer to 2 per thousand.(Thornton 1982) Manning assumed a life expectation at birth of 27.5 years, fertility of 43 per thousand, mortality of 38 per thousand, and an initial net rate of natural increase of 5 per thousand.(Manning 1986, 1990)

6. **Age and sex composition of African populations.** The age and sex composition of captive exports, along with the resultant impact on African population, was only gradually recognized as an issue of fundamental importance. Manning argued that the character of slavery – not only in various African regions, but in the New World and in the Middle East – was determined by the age and sex composition of slave populations.(Manning 1981) Thornton demonstrated the African potential for avoiding depopulation by exporting men rather than women, but he also cautioned that African population may nevertheless have been reduced because of captive exports. Thornton and Manning, using different methods, each estimated that the adult male-female ratio fell to 80 men per 100 women for the western coast of Africa.(Thornton 1980, 1982, Manning 1986) The age distribution of captive exports has undergone less critical discussion than the sex distribution, but the concentration of captive exports among young adults is crucial to Manning's argument that the African population declined from 1750 to 1850.(Manning 1985)

7. **Hardest hit regions.** Regional studies will ultimately provide the basis for a continental assessment of the demographic impact of slave trade. The continued debates at the regional level, and the virtual absence of studies for many regions, suggest that it will be some time before the overall issue is resolved.[70] There are two studies which attempt region-by-region assessments of demographic impact along the western coast of Africa, by Thornton and Manning; the latter finds the results to be more severe because of the assumption of a higher net domestic loss ratio.(Thornton 1982, Manning 1987) In addition to debates about the number of captive exports by coastal region, there is the question of whether the captives exported from any portion of the coast came from the coast or the interior. Lovejoy challenged Manning's assertion

[70] Among the studies giving close attention to the demography of slavery in African regions are Curtin (1975) on Senegambia, Anstey (1975) on the Congo basin and the Bights of Benin and Biafra, Patterson (1975) on the northern Gabon coast in the nineteenth century. Miller (1975) on Angola, Northrup (1978) on the Bight of Biafra, and Manning (1982) on the Bight of Benin.

that Bight of Benin captives came dominantly from the coast; Inikori echoed Lovejoy's claim and also challenged Northrup's assertion that Bight of Biafra captives came dominantly from the coast.(Lovejoy 1983, Manning 1982, Inikori 1985, Northrup 1978)[71]

8. **African growth or decline.** The overall question of African population growth or decline in the era of slave trade is seen to depend on the resolution of many subsidiary questions. Some global estimates have nonetheless been proposed, with varying degrees of care. Diop-Maes estimated a decline from a fifteenth-century continental population of 800 million to a nineteenth-century population of 200 million.(Diop-Maes 1985) Manning asserted, for the western coast of Africa, a decline from a 1750 population of roughly 25 million to an 1850 population of between 4 and 7 million less.(Manning 1985) On the other hand, Fage, Thornton, and Miller asserted rough population stability for various regions of the continent, and Caldwell asserted a continental population increase of 2.5 per thousand per year during the slave-trade era.(Fage 1975, Thornton 1982, Miller (JAH), Caldwell 1985)

9. **Regional variation.** At least as important as the levels of fertility and mortality are any cyclical or secular changes in fertility and mortality that may have taken place. Fage and Thornton suggested that African fertility may have increased in response to enslavement, while Manning argued against this possibility.(Fage 1969, Thornton 1982, Manning 1981, 1985) Caldwell has restated arguments (based in part on the work of Miracle) that maize and other new crops caused population to increase.(Caldwell 1985, Miracle 1966) Joseph Miller emphasized the importance of drought and famine in the southern savanna, and suggests that these caused mortality to shoot up to occasional peaks, in between which the net rate of natural increase was sufficient to overcome losses to slave trade.(Miller 1982)

10. **Continental enslavement.** The magnitude and demographic effects of enslavement within sub-Saharan Africa, difficult to measure, tended to be left out of account. In exceptions to this pattern, Thornton and Manning accounted for the increased domestic enslavement of females as a concomitant to the export of captive males; Inikori offered summary estimates of the number held in captivity in Africa; and Lovejoy sought to compare the sizes of enslaved populations in Africa with that in the Americas in the late nineteenth century.[72]

11. **Counterfactual population.** The counterfactual African population, the hypothetical total population that would have existed if captive exports had not occurred (or, alternatively, the counterfactual difference between the actual and the hypothetical populations), has been estimated three different ways. Inikori, by comparison with American rates of growth, estimated a counterfactual addition of 112 million Africans by 1880 if slave trade had not occurred: this corresponds to a rough doubling of African population.(Inikori 1982) Caldwell, reflecting on African growth rates, estimated a counterfactual addition of about 4 million persons by 1880, or about 15% of the population of the western coast of Africa.(Caldwell 1985) Manning, by method of simulation, estimated a counterfactual 1850 population of the western coast of Africa at 50 million rather than the estimated actual 23 million.(Manning 1985) None of these counterfactual estimates, however, has been able to account for counterfactual Malthusian checks of famine and epidemic, nor for changes in fertility and mortality for other reasons.

[71] Lovejoy later acknowledged that the evidence supported Manning's interpretation.(citation)
[72] Inikori, Thornton, Manning, Lovejoy – give numeric estimates of those enslaved proposed by each author.

In methodology, all estimates of the impact of captive exports on African population involve two basic steps. First is the comparison of a flow of captives to a stock of African population. We have defined this above as the "rate of captive emigration" (variations of it can be defined to address issues of age and sex distribution). The second step is a judgment (based on the size of this ratio) on the direction and magnitude of change in the stock of African population: we have above labeled the result of this judgment as the "rate of loss to enslavement," in simple terms, and as the "net growth rate under enslavement" in net terms. Contributors to the debate have varied somewhat on their estimates of the flow of captives from Africa, they have diverged rather more on their estimates of the stock of African population, and they have differed most of all in estimating the impact of a given rate of captive emigration on African population. These differences are both empirical and methodological, but here we will emphasize the variety of methods applied to these studies, in the hope of separating out the strong from the weak.

John Fage's 1969 and 1975 studies represent in many ways the beginning of this debate, and his methods were more sophisticated than earlier guesses. He estimated the stock of West African population by projecting backward from an estimated 48 million inhabitants in 1940, at growth rates assumed to have increased exponentially from 0.025% per annum in 1600 to 1% per annum in 1900. His annual flow of exports was taken as the average eighteenth-century New World captive imports from West Africa, as given by Curtin, or roughly 40,000 per year. Finally, Fage assumed that the simple loss/emigrant ratio was 1.0, so that if 40,000 persons were born in West Africa in the same year 40,000 persons were removed in slavery, then net population growth was zero. This approach, which included no further assumptions as to the composition of the African or export populations, led Fage to the conclusion that the number of captive exports was sufficient to halt but not to reverse West African population growth.

Roger Anstey applied a somewhat different method to the Congo River basin and to the Bight of Biafra, and reached conclusions similar to those of Fage.(Anstey 1975) He assumed a loss/emigrant ratio of1.0, as did Fage, but he assumed a higher net rate of natural increase than did Fage. His analysis was in terms of population densities rather than levels of population: for each region of the coast, Anstey asked whether the "catchment area" from which captives were drawn was large enough, at his estimated levels of density, to produce enough new population to offset the loss of captives. Northrup criticized Anstey's analysis of the Bight of Biafra, but reaffirmed Anstey's conclusion that the area had not suffered population decline.(Northrup 1978)

Thornton's region-by-region analysis was a more sophisticated version of Anstey's approach, particularly because he paid explicit attention to the sex composition of both African and emigrant slave populations.(Thornton 1982) He concluded (by means discussed above) that a rate of captive emigration of 2.7 per thousand represented a break-even point, above which African population would decline. For each of seven regions, and for each 50-year period from 1600 to 1850, Thornton estimated the population density necessary to avoid decrease in population. He then considered more informally whether the regions were likely to have had the requisite population densities, and concluded that only in Angola had there been insufficient density.

Manning, in a study of the Bight of Benin, calculated decennial totals of regional captive exports, and then allocated total exports among five regional ethnic groups for each decade. His allocations were based on the proportional representation of these ethnic groups in listings of New World slaves by ethnic origin. These captive exports by ethnic group were then compared to populations projected by a method similar to that of Fage as described above, and the results suggested substantial population decline among the coastal Aja peoples, especially 1690-1780; he argued that Yoruba became numerous among those enslaved only in the 1780s.(Manning 1982) Lovejoy and Inikori initially contested these results, arguing that most captive exports in the eighteenth century came from the interior rather than the Aja of the coast, but Manning's analysis seems to have held up.(Lovejoy 1983, Inikori 1985) (See note 36 or 25)

Diop-Maes proposed estimates for the influence of slave trade on African population inspired by the work of Cook and Borah in estimating pre-Columbian populations of the Americas.(Diop-Maes 1985, Cook and Borah 1971) At best, this approach is analogous to what Philip Curtin has called the "capacity estimates" of the volume of slave trade: a maximal population is estimated for various villages, towns, or regions, based on evidence from archaeological remains or traveler narratives, and this population is then projected to a larger area to provide a continental estimate. This is what Cook and Borah did for the Americas, but they did intensive work on at least one area (the valley of Mexico), for which Diop-Maes has no equivalent. Then Diop-Maes assumed that the Amerindian population fell to 25% of its original level within a century of the European conquest, and argued that the African population must have fallen by the same ratio, but over a slower period of four centuries. She applied a multiplier of four to an estimated 1850 African population of 200 million (itself double the other estimates we have discussed) to obtain an estimated African population of 800 million in 1450. Unfortunately, she proposed no detailed mechanism linking these population estimates to the flow of captives exported.[73]

Inikori's method of projecting a counterfactual population in the absence of slave trade bore some similarities to that of Diop-Maes. In his 1982 estimate (a modification of his initial 1978 estimates), Inikori noted that a cumulative total of some 430,000 captive imports to the United States by 1810 had led to a stock of black population of 4.5 million in 1863.(Inikori 1982) Striking a ratio of these two figures, halving it to be more conservative, and applying this multiplier of roughly 5 to the cumulative total of some 30 million captives which he estimated to have been exported from Africa, he concluded that there would have been 112 million additional Africans by 1880 if there had been no slave trade. While Inikori's accompanying argument included many relevant points, his estimates reduce to the application of a speculative multiplier to a cumulative total of captive exports drawn from many different centuries.

Caldwell, in his review of the demography of African slavery (published in 1985 but written over a decade earlier) touched on all the main issues. He considered rates of fertility and mortality, rates of emigration and loss, levels of African population; he addressed the composition of African and emigrant population tangentially. But since his techniques were limited to the pencil-and-pad level, he did not address interactions among these factors, and underemphasized the importance of the interaction among emigrant sex composition, emigrant

[73] Diop-Maes (1985); Curtin on capacity estimates.

age composition, slavery-related mortality, and declining African fertility.(Caldwell 1985, Manning 1981, Caldwell 1982)

All of these methods are speculative to a significant degree. Even the approach of attempting to assemble empirical data on the population of a small African region involves much speculation as well, though a good example of such an effort may be found in Johnson (1978). In addition, further factors need to be taken into account beyond those discussed in this section – in particular, the limits placed on population by periodic famine and epidemic (Miller 1982). But since global estimates of the impact of slavery on African population must rely heavily on deductive models, at least for the foreseeable future, the point is that such models should focus on maximum internal consistency, and on consistency with demographic principles and available data. By these standards only the studies of Thornton, Caldwell, and Manning go beyond the level of elementary speculation.

Evidence is available (or can be developed) which will permit an increasingly detailed assessment of the demography of African slavery. This evidence lies in each of the areas discussed above, and in some additional areas.

Important work continues to appear on the export of captives from Africa, and provides improved data on the volume, the age and sex composition, and the mortality patterns of captive exports. In particular, Eltis's work in British archives provided a greatly improved picture of nineteenth-century slave trade.[74] In addition, it may be necessary to go back over some research that has already been completed: since the debate on the volume of Atlantic slave trade has focused on the cumulative total of captives, some researchers noted only the total number of captives delivered when in fact their sources would have enabled them to give a breakdown by age and sex - for instance, Stein (1979) on the French slave trade. Since age and sex composition are now understood to be crucial to resolution of the debate on African impact of slavery, it would be beneficial to review the primary data in such cases. (In the case of the French slave trade, the data drawn together by Mettas (1978-1984) were presented in an ideal form, giving maximal information on age and sex distribution of captive exports; these data were fully incorporated in the Eltis et al dataset.)(Mettas 2 vols.)

Other sources of information. Data on the demographic and ethnic composition of New World slave populations represent a vast resource on which Africanists have drawn only sparingly. Studies by Higman and Debien are among the best known contributions, but the overall literature is large.(Higman 1984, Debien 1974) It is true that linking data on New World slave populations to conclusions on African demography involves a string of assumptions that introduces a certain delicacy and insecurity into the analysis. But as Fallope has shown for the case of Cap Lahou emigrants to the French Antilles, research on both sides of the Atlantic can yield a trustworthy, if partial, picture of the demography of an African ethnic group.(Fallope 1985, Manning 1982)

Additional research has appeared on slavery and enslavement on the African continent.(Robertson and Klein 1983, Cordell 1985, Miller 1998) This research, generally descriptive rather than quantitative, provided increasingly specific information on means of enslavement, the age

[74] Eltis in G&H and after.

and sex composition of captives, mortality of captives, and the incidence of slavery by African region.

The voluminous if disparate literature of African travel narratives is an important if relatively intractable resource for demographic history. To the degree that analytical work is able to pick out key variables for study – such as fertility, mortality, and the composition of captive populations – it may become possible for researchers to go systematically through portions of the travel literature and compile useful observations on those variables.[75]

An additional area in which further research will be helpful is climate.(Miller 1982, Becker 1985, Patterson) Such work should help to clarify the degree to which drought and famine limited African population regardless of the impact of slavery; it should also help to clarify the degree to which slavery aggravated famine and drought. Agricultural evidence too needs to be drawn together to help determine whether African nutrition improved in the era of slave trade, as Caldwell argued, whether nutritional improvements preceded the full impact of slave trade, or whether nutrition worsened during the era of slave trade.(Caldwell 1985, Wigboldus 1986)

North, Northeast, and East Africa

The literature on the volume of slave trade and the accompanying social interactions for the rest of Africa is, by comparison, vague and disaggregated. The heroic effort of Ralph A. Austen to assemble quantitative estimates of slave trade out of a scattering of sources—work conducted in the 1970s and 1980s—remains as the best overall estimate. Various additions to his estimates have arisen since, especially in the work of Gwyn Campbell on slave trade in southeastern Africa and the summaries of Tim Fernyhough on Ethiopia.[76]

Conclusion

It is now agreed that slavery was a factor in African demography: the literature has passed beyond the strange consensus of the 1960s and early 1970s which implicitly and explicitly portrayed the demographic impact of slavery on Africa as virtually negligible. Population in at least several major regions of the continent is recognized to have been limited and perhaps reduced in size, and its age and especially sex composition distorted. At the same time, recent work has confirmed that African society avoided the devastating losses of population that accompanied external impact on the Americas and the Pacific islands. The role of polygyny in minimizing the long-term demographic losses through slavery is known in increasing detail; mechanisms for minimizing slave mortality may also have been important in some cases.

The African demographic regime survived the slave trade in recognizable yet distorted form. The nature and the magnitude of the distortions are emerging in broad outline. Decrease in population and decline in the sex ratio have been demonstrated convincingly for the Bight of Benin, Angola, and Mozambique in certain periods, and the margin of debate is narrowing for

[75] fn on data mining)
[76] Austen estimates; Campbell estimates; Fernyhough.

other regions. A combination of available evidence and improved methods should permit the development of consensus on some more specific hypotheses: the most significant such hypotheses will center on levels of African fertility and mortality, and on the age and sex composition of captives.

The hope for a good understanding of the demography of African slavery lies in the combination and interaction of global and local studies. Biraben's suggestion that an accumulation of local studies might ultimately pave the way for a global estimate is plausible to a point but does not take account of the paucity of local data. Meanwhile, the initial benefit of the global studies is that they have gradually revealed the range of inappropriate assumptions and have focused attention on key variables. Local studies can then incorporate revised assumptions, collect new data on key variables, and lead to new formulations of the global assessment. Henige's conclusion that global studies are trapped at the level of ideology reflects the assumption that scholars are also trapped at an unchanging level of methodology.(Biraben 1985, Henige 1986) The conclusions of both Biraben and Henige that global studies should be abandoned reflect an unwarranted defeatism. In fact the techniques available to demographic historians have only begun to be applied to African data: proper use of existing methods and development of new methods may greatly increase the explanatory power of the admittedly limited and dispersed store of African demographic data.

The limits on the study of African demographic history in the era of slavery may ultimately prove to be an ironic strength. Demography has generally focused on closed populations, assuming migration to be negligible because it is an intractable factor, far more irregular and difficult to analyze than fertility and mortality And yet migration has historically been a demographic process of the first importance. For Africa in the era of slave trade, however, far more data are available on migration than on fertility and mortality: the main hope of learning about African fertility and mortality lies through analysis of the forced migration of captives. Pursuit of research on this topic, both at global and local levels, has the potential of contributing to two developments which are much to be hoped for: the development of an improved methodology for analyzing the impact of migration, and a shift in the focus of historical demography towards inclusion of migration as an essential rather than a peripheral part of the analysis.

The debate on African consequences of external slave trade has been long and, so far, inconclusive. The topic turned out to be complex; data were scattered and seemed incoherent. Discussion was segmented into regional, temporal, and disciplinary subgroups, thus slowing communication. There was no common set of variables or terms, but instead an eclectic set of approaches and conclusions. For a long time, the discussion was simply dropped. Nevertheless, advances did come out of the debate. The significance of gender and sex ratio became important, and it became clear that declining population was indeed a possibility for at least some times and places. Gradually and implicitly, there developed comparisons of slave trade among regions: in West Africa, Central Africa, East Africa, and northern Africa. Similarly, comparisons of enslavement in coastal and interior regions became more common.

More attention to demographic principles would have helped at every point, though principles alone could not compensate for missing data. For instance, the difference between analyzing migration and population growth through crude rates and age/sex-specific (or

composition-specific) rates came to be noted increasingly, but was rarely addressed significantly. In any case, any future analysis of African population as influenced by external slave trade must account for previous concerns and debates, especially the debate that fluctuated in intensity from the end of the 1960s into the 1990s.

Chapter 4

Twentieth-Century Demographic Rates

Vital Rates, 1950-2000
Vital Rates, 1890-1950
Conclusion

Chapters 4 through 6 are to assemble data on vital rates for African populations, working from the twentieth century back to the seventeenth century, to provide a basis for estimating changing population totals for Africa. This chapter addresses African vital rates from the 1890s through the twentieth century. It focuses especially on rates of birth, death, migration, and net population change. The overview begins with the best-documented period, the late twentieth century, and then addresses the period from 1890 to 1950. United Nations statistics are the most consistently and comprehensively revised. While the may be further revised with additional research, these figures reflect the best in current scholarship, and are most helpful in comparing regions and time periods within Africa since 1950.

Vital rates, 1950-2000

In nuptuality and childbirth, the average African age at first marriage increased from 1950 to 2000, and moreso among women than men. Marriage remained the rule—few adults remained unmarried. The rate of polygyny remained high, especially in West Africa and the Sahel, where 30-60% of women 35-44 were in polygynous marriage. Polygyny was slightly less widespread in Central Africa and still less in East Africa (proportions of women 35-44 in polygynous marriage ranged from 4% Madagascar to 39% Uganda) and least of all in Southern Africa (14%). As of 2000, one of three women aged 40 was in a polygynous marriage; one of two had ever been in polygynous marriage. Further, divorce and remarriage were common but poorly documented. West Africa and the Central African savanna had the highest rates of polygyny in the world. It is worthy of note that these were the regions where women's education and literacy were at the lowest levels in recent times and from which the largest numbers of male captives were extracted during the centuries of slave trade.

In fertility, as of 2000 the median age of sub-Saharan African mothers at first birth was 19.7 years: half of women had their first child before age 20. The average number of births per mother in the region was 5.4, well above other world regions. Old patterns of long birth intervals (two years or more), reinforced by long breastfeeding and postpartum abstinence, continued to be important. There was little in the way of modern contraception; incidences of abortion were badly documented, but it appeared to be uncommon. On the other hand, sharp urban-rural distinctions in fertility have emerged, as urban fertility has declined more rapidly than rural fertility.

African rates of mortality declined consistently from 1950 to 1990, but after 1990 there was stagnation in some areas and dramatic reversals in others. Of 48 African nations surveyed,

20 still had declining rates of mortality. Of others, Benin, Nigeria, and Ethiopia faced stagnation; expectation of life declined by from one to five years in Togo, Mozambique, and Tanzania; and the decline was from 5 to 12 years in Côte d'Ivoire, Cameroon, and Kenya. In Southern Africa, the decline in expectative of life was greater than 12 years. As Tabutin and Shoumaker (2000, p. 466) put it,

> South Africa and Botswana's growth rates declined from 2.0 and 2.8% respectively in 1990-94, to 0.6 and 0.9% ten years later. This is a unique event in history.

African maternal mortality remained high in 2000; infant mortality rates had declined substantially in Africa since 1950, but at a slower rate than for other world regions. Most births were still at home and without medical personnel. Recent statistics have shown an excess mortality for girls, even though boys have inherently higher mortality than girls: this documents a previously unsuspected African pattern of extra care for boys or relative neglect of girls. With all of these changes and continuities, the age structure of African populations—the dimensions of a population pyramid—remained virtually unchanged after 50 years.

Migration to urban areas, however, provided a profound change in African population. Sub-Saharan Africa's urban population rose from 20 million in 1950 to 220 million in 2000; in the same period the rural population rose from 156 million to 430 million. In 1975 there were only four cities with populations exceeding one million—Lagos, Kinshasa, Cape Town, and Johannesburg. By 2000, at least 27 cities had populations exceeding one million (19 of these were national capitals). Urbanism was unevenly distributed across the continent: in 2000 Southern Africa was 58% urban, East Africa was a much lower 39% urban; and in between were West Africa with 39% urban and Central Africa with 35% urban.

International migration of sub-Saharan Africans took place primarily among countries within the region. Detailed documentation is quite poor, but the overall patterns remain clear. In 2000, there were 15 million international migrants within Africa, who comprised 2.2% of the total population. The total number of migrants had not changed much since the 1960s, but the proportion of Africans who were international migrants in the 1960s had been a higher 4%. Africans in 2000 had a higher rate of international migration than elsewhere in the developing world: the African 2.2% compared with 1.4% in Asia and 1.1% in Latin America and the Caribbean. Almost half of all international migrants from Africa in 2000 came from West Africa (7 million), while 5.3 million migrants came from East Africa and lesser numbers came from other regions. Refugees expanded in number with Africa's political conflicts. A continental figure of 100,000 African refugees in 1960 rose to 5 million in the mid-1990s, and declined to 3 million in 2000. Even at the latter date, Africa had a quarter of the world's refugees. Another growing component of African migration was migration to the wealthy areas of Western Europe, North America, and Oceania: this flow rose from 17,000 per year in the 1960s to 80,000 per year in the late 1980s.

Vital rates, 1890-1950

For the colonial era (roughly 1890 to 1950), three types of new data are enriching our understanding of African populations. First, the documentation of post-colonial populations, discussed just previously, sets methodological standards and empirical figures to which the

colonial-era estimates must be linked. Second, there have been numerous studies of the colonial era, which rely on exploration of published colonial documents and the surveys underlying them (although there has not yet been any attempt to aggregate these studies into global population estimates for the colonial era).(Cordell and Gregory 1994, Fetter 1990)[77] Third, the comparison of colonial African data with the expanding knowledge of contemporaneous data from other parts of the world provides a basis for making improved estimates of African demographic rates.(Maddison 2001) In our analysis of the colonial era, we have drawn on each of these types of evidence, and have compiled them into an array of estimates of decennial growth rates as they were affected by a range of social, political, economic, and demographic variables.

***Comparison with postcolonial documentation*.** Patterns of fertility, mortality, migration, and net growth changed rapidly. Were there some underlying patterns of similarity that persisted even with these major changes?

Studies of colonial Africa. The main authorities with which to begin in making estimates of African demographic rates before 1950 are colonial-era annual reports and compilations, plus occasional large-scale reviews (notably the massive 1948 survey by R. R. Kuczynski) and postcolonial scholarship reviewing the documents of the colonial era, (notably the 1987 collection of essays edited by Dennis Cordell and Joel Gregory and the 1990 collection edited by Bruce Fetter).(Kuczynski 1948, Cordell and Gregory 1994, Fetter 1990.) There are many other commentaries on aspects of colonial African demography, on which I have drawn in varying degrees.(Sautter 1966, Cordell 1985) Official reports on colonial-era populations are the principal sources with which the authorities have worked; of these, the censuses and estimates for South Africa provide the longest time frame.[78]

Comparison with other regions. If it may be assumed that changes in population growth rates throughout the tropics were somewhat similar, then it is relevant to consider growth rates in the well-documented population of India as proxies for African growth rates. There has been insufficient comparison of demographic rates among tropical regions. While each region necessarily has its demographic specifics, the general parallels in ecology, disease environment, colonial domination, and scanty records require that comparative work be expanded in order to ensure that advances in the demographic study of any one region can be considered for application to other regions. Thus, the application of Indian proxies for African data is the utilization of detailed data—although from a distant and distinctive region—in place of sheer speculation on African demographic rates. In addition, as the remainder of this section shows, we proposed modifications to Indian data based on known distinctions between Indian and African demography.

[77] The present study develops continental estimates, but does so deductively from aggregate populations and estimated growth rates, rather than inductively through aggregation of local studies.
[78] Union of South Africa, *Official Year Book of the Union* (Pretoria). For a major recent assessment, see Tukufu Zuberi et al. 2005.

Table 4.1.
India: Decennial growth rates (% per year) for provinces and states[79]

	1871 - 1881	1881 - 1891	1891-1901	1901-1911	1911 - 1921	1921-1931	1931 - 1941	1941 - 1951	1951-1961
Tamil Nadu	-0.12	1.57	0.94	1.07	0.46	1.09	1.19	1.47	1.31
Berar	1.82	0.81	-0.51	1.04	0.06	1.13	0.46	0.49	1.91
Ajmer-Merwara		1.64	-1.28	0.50	-0.12	1.24	0.41		
Bombay Prov.	0.06	1.40	-0.18	0.58	-0.17	1.26			
Coorg	0.58	-0.30	0.43	-0.32	-0.66	-0.03	0.33	3.12	
Madras	-0.04	1.35	0.70	0.81	0.22	1.00			
Baroda			-2.10	0.40	0.45	1.40	1.57		
Mysore	-1.87	1.68	1.14	0.47	0.29	0.93	1.12	2.16	
Rajputana		1.58	-2.09	0.80	-0.67	1.32			
Unweighted Mean	0.07	1.22	-0.33	0.59	-0.02	1.04	0.85	1.81	1.61

Table 4.1 shows decennial growth rates calculated from census returns for regions of south and central India for which the administration was consistent. The Indian case suggests that there were no growth rates as high as 2.0% before 1940, and that growth rates as high as 1.0% were rare before 1920. Of forty-one observations from 1871 to 1921, ten showed annual growth rates of over 1%, eight showed growth rates between 0.5% and 1.0%, nine showed growth rates between zero and 0.5%, and fourteen showed negative growth rates. The apparently high growth rates of the 1880s (averaging 1.2%) are probably an artifact of improved enumeration in 1891.

India cannot, of course, be taken as a straightforward model for Africa. It was under stable British administration from the early nineteenth century. There are reasons to expect that African growth rates should have been lower than those for India, especially in the nineteenth-century circumstances of slave trade and in the tumultuous era of conquest and establishment of European administration.[80] Overall, however, the available Indian growth rates are very helpful in suggesting the range of African growth rates in contemporary periods.

[79] These growth rates were calculated only for Indian territories for which the boundaries remained virtually unchanged over the full century. Sources: Census of India (various titles and publishers, for decades ending 1881 to 1961); Visaria 1894; Barrier 1981; Ira Klein 1989; Klein 1990; Klein 1994; Klein 2001; Guha 1991; Dyson and Maharatna 1991; Mohanty 1992. Population figures for Tamil Nadu and Berar are from Guilmoro 1992 and Dyson 1989. We calculated growth rates for the remaining territories listed, working from summary statements of the decennial censuses of India for territories where boundaries changed little or not at all. Populations of these territories varied from several thousand (as in Coorg) to several million (as in Madras)—so the unweighted mean of the provincial figures is illustrative rather than representing an average growth rate for India. Government of India, Census Commissioner, *Census of India* [title varies], 1881-1961. See also the appendices in P. B. Desai, *Size and Sex Composition of Population in India, 1901-1961* (Bombay: Asia Publishing House, 1969).

[80] Population practices in Africa and India differed in this period in that Indians practiced some female infanticide, selective non-nurturing, and had British health services in parts of the sub-continent. Other reasons why Indian

Conclusion

By the end of the chapter, I should present the best estimates and the range of figures for African birth, death, and migration rates, 1890 – 2000, in age-specific and sex-specific terms. Also net growth rates – basic estimates plus the range, over time.

Estimates of colonial African population, made during and since the colonial era, have been too low. Growth rates have been assumed to be too high. Indian growth rates are argued to be appropriate proxies for African population growth rates, since there was no reason for African population growth rates to be higher than those of India.

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fertility rates may have been lower than African rates include Indian prohibitions against widow remarriage, in contrast to African practices of encouraging widow remarriage. On the other hand, mortality rates may have been higher in Africa, compensating in part for this difference. Indian populations were undercounted, but not as seriously so as in Africa. Indian data suggest a common decline in fertility rates in the early twentieth century, and African data suggest a parallel decline, at least for some regions. These comparisons should be explored in more detail.

Chapter 5

Precolonial Demographic Rates and Levels

Vital Rates in Settled Populations
    Kongo
    Manguenzo
Vital Rates as Affected by Migration
    Angolan slave trade
    Populations of Western Africa
    Partition of captives: those destined for Africa and abroad
Net growth rates
Conclusion

The rates of entry into and departure from human populations determine the character and direction of population change: in particular, the resultant of these processes of fertility, mortality, and migration yields the size and the rate of net population change. For precolonial Africa, the available data on these vital rates are relatively scarce. The availability of detailed data and systematic estimates on the volume of captives leaving sub-Saharan Africa provides one important set of data on rates of migration. The volume of captives addresses other flows of migration only indirectly; it influences but does not determine rates of birth and death.

Several types of information may be drawn upon to develop estimates of precolonial African vital rates. First, demographic theory and systematic collections of demographic patterns. Demographic theory carries out systematic calculations on birth, death, and migration, but has never been able to predict the detailed shifts in population through the deductive approach of algorithms. Instead, demographers have used the inductive approach of collecting detailed statistics on large numbers of populations, then combining and comparing them to develop "model populations" and "model life tables" showing sets of relations within populations. The two best-known sets of model life tables were prepared at Princeton University and were published in 1966 and 1983. With these model life tables, once one has determined a certain amount of information about a population, one may estimate other aspects of the same population.(Coale and Demeny 1966, 1983) Second, some detailed descriptions of precolonial African populations—such as censuses, baptismal records, and population registers—have survived in the historical record, and these may be analyzed, in association with model life tables, to estimate rates of birth and death. Third, the historical record also includes some estimates of rates of migration which may be analyzed according to parallel principles. Fourth, one may consider population records and estimates for regions outside Africa but which are arguably comparable to Africa's demographic conditions.

The big questions for this chapter are: what were rates of fertility, mortality, migration, and population growth for populations throughout Africa in times from 1650 to 1900? By "migration" we mean not only the export slave trade but also the process of continental

enslavement and its toll, which adds another dimension of variance to the analysis. To calculate these rates with precision for a given population, one must have the population by age at the start and end of a period, births by age of mother within that period, deaths by age of decedent within the period, and migrants (in or out by age of migrant) within the period. More commonly, we have incomplete fragments of data: population totals without respect to age; births with no data on the mother; deaths without age at death; and migrants without age or sex of the migrant. In addition, data may be incomplete and inconsistent in their degree of completeness over time.

Vital Rates of Settled Populations

We have scattered evidence on births, but almost no direct evidence on deaths and very little information on births per mother in precolonial Africa. Such evidence as we have on deaths comes from estimates of overall mortality based on the shape of the age pyramid for a population. John K. Thornton, working with data from the long Portuguese colonial experience in Angola, was able to retrieve several documents that were remarkably specific about the characteristics of population, and he launched an effort to estimate rates of birth, population size, and rates of net population growth from them. Based on these analyses, Thornton proposed a series of rates of birth and net population growth for precolonial Angola; Thornton and other scholars then used these rates in estimates of population change over large spaces and times in Africa. The analysis in this section is to review Thornton's initial analyses, and to see if they can be confirmed.

Thornton on Kongo.. John Thornton summarized several past estimates of the aggregate population of the Kingdom of Kongo, from 1588 to the early twentieth century.(Thornton 1977a) This kingdom, having converted officially to Christianity before 1500, gained consistent attention from Europeans, notably officials of the Catholic Church, and is therefore unusual among African regions in having numerous estimates of its population from early times. Thornton summarized and commented on several of these estimates of total Kongo population: 2 million in 1588 (Duarte Lopes); 2 million in 1675 (Giuseppe Maria da Busselo); a 1687 estimate of Manuel de Saa that 600,000 souls per year went without Communion for lack of priests (Thornton concludes that this is consistent with a population estimate of 2 million; 1 million in 1733 for the province of Sonyo alone (Antonio Maria da Polinago); and an estimate by the modern scholar Georges Balandier that the population began at an early figure of 2 million and gradually declined to 1 million.(Thornton 1977a, pp. 507-508)

Thornton suggested, with good reason, that these aggregate estimates were inflated. He proposed instead to develop population estimates from historical documentation of Kongo, especially baptismal records. In a long section of the article he showed how Capuchin and other priests sought to baptize as many Kongo children as possible. He argued that the Kongo population sought systematically to baptize their infants and young children but showed no interest in baptism of adults or older children. Thus priests were welcome and indeed solicited for baptism, but were encouraged to leave communities once infant baptisms were completed, to return in another year or so.[81] Baptismal lists in Kongo, at best, listed the name, age, and sex of

[81] Priests filled the role of *nganga* (healers, witch finders, etc.). Baptism came to be linked to *kimpasi*, an initiation for difficult times such as famine or pestilence: death and resurrection of initiates. Baptism as the Christian initiation. (check Thornton article) Ibid., 509 – 515.

the baptized, his or her parents, and occasionally a godparent. A good number of baptismal records survive, though they are generally scattered. The most thorough such list, a detailed 1673-1701 baptismal and marriage list kept by Capuchins at the behest of Prefect Francesco da Pavia – deposited at the Capuchin hospice of Sao Antonio in Luanda, is described by Thornton as "apparently lost in World War II."

The specific baptismal registers that Thornton chose to analyze come from districts of eastern Sonyo, a coastal province of Kongo. He combined several sets of baptismal registers created between 1701 and 1706, attempting to adjust the ages of children for the different years in which baptisms were recorded. Out of these materials he was able to create a population pyramid showing the number of children baptized from age under 1 up to age 5 (but combining males and females). He then compared the ratios of age groups in this pyramid with ratios that can be calculated from the Coale and Demeny model life tables.[82]

Thornton's calculations: **Libome** etc: oL1/oL2 = 400/699 = .572. **Kiova** etc: oL1/oL5 = 452/1730 = .262. Thornton concluded the Model East, level 4, with inherent growth rate r = 7.5/oo, fit these population ratios. He then noted that, in this model population, oL1 is 3.5% total population, so that the total population for Libome etc. could be estimated as 400/.035 = 11,400 (11,429).[83]

The problem with Thornton's linkage of his data from historical populations to the specific model population he chose is that, while Model East, level 4, r=7.5/oo fits the limited data from his historical population, it is not the *unique* fit to the population ratios in his data. In addition, as will be shown here, several other model populations also fit the same ratios as those calculated from Libome and Kiova. Each model population includes a general mortality level, a range of fertility levels, and one of four characteristic life-course patterns (Coale and Demeny labeled these North, South, East, and West). Thornton, in choosing level 4, chose a mortality level yielding an expectation of life at birth of 27.5 years; he chose a mix of fertility and mortality that yielded a net rate of population growth of 7.5 per thousand per year. While Thornton carried out quite a few calculations, he seemed satisfied with these rates of mortality and net population growth when he encountered them, and did not consistently consider how widely these key elements of population change might have varied.

Table 5.1 shows information from a selection of model populations with varying rates of mortality, fertility, and net population growth, all of which provide a close match to the population ratios that Thornton was able to calculate from Kongo baptismal records. If the baptismal records had been more systematic and had covered a longer age span, one would be able to narrow the range of demographic rates that can fit the data. Nevertheless, without independent information on the number of adult women and their birth rate, it is not possible to exclude a rather wide range of possible sets of demographic rates. Thornton tried to use model life tables to make some estimates of total births and total population from *numbers* of births, but

[82] "I have combined the male and female rates in Coale & Demeny, *Tables*, 468 and 594." While C&D recommend West as first test, and Brass recommends North for Africa, "I found that the 'East' table fits the two ratios I have far more closely than any other model." He used linear interpolation – for what? I guess to combine male and female – yes. Thornton used C&D model East, level 4, growth rate of 7.5/oo. There oL1/oL2 = .577; oL1/oL5 = .256.
[83] Ibid., 517.

there was no historical data from which to estimate *birth rates*, the numbers of children per mother.

Table 5.1. Alternative Population Models Matching Kongo Data
Source: Thornton (1977); Coale and Demeny (1983)

Source	oL1/oL2	oL1/oL5	Mortality e(0)	Fertility	Growth
CD:E5;7.5					
CD:E4;7.5					
Data	**.572**	**.262**	**27.5**		**7.5/oo**
CD:E3					
CD:E2					
CD:E1					

In addition, neither the Coale and Demeny model populations nor Thornton's analysis accounted for the possibility of migration. While the assumption of no migration simplifies analysis and provides useful basic population ratios, and while it may have been valid in practice for numerous African populations, in general it is necessary to account for migration, especially since enslavement and forced migration were a steady influence in West and Central Africa from the sixteenth through nineteenth centuries.

Based on these estimates of ratios among childhood age groups, as linked to model life tables, Thornton sought to estimate the size of the total populations including the baptized children. If he had developed a wider list of the model populations that were close to fitting his estimated age ratios, he would have been able to show a range of population estimates rather than a single estimated figure. Nonetheless, his estimates can be seen as sensible estimates for total population. In later parts of the article, he gathers numbers of baptisms for each region of the Kongo kingdom and with them prepares an estimate of the total population of Kongo in the eighteenth century: his overall figures are 509,250 for 1650 and 532,000 for 1700 for a total region of 130,000 square kilometers.

In sum, Thornton's technique has been helpful to estimating the population of regions for which large numbers of infant and childhood baptisms have been recorded. But it has made only minimal progress in narrowing the estimated bounds of historical African rates of mortality and fertility. The most basic weakness of Thornton's work is that he did not fully explore the range of model populations relevant to his baptismal data, and did not explore the range of fertility and mortality rates that might be consistent with historical evidence. In addition, Thornton may have made errors by neglecting the possible of migration in the populations he studied, and may have underestimated the number of infant deaths before the recorded baptisms, which may mean that he underestimated the infant mortality rate.

Thornton on Manguenzo. In a further application of his technique, Thornton focused on the region of Manguenzo, a northern frontier region of the Kongo Kingdom, in which recently established villages were visited by French priests in 1774 and 1775. The priests recorded a total of 711 baptisms; ages of the baptized were recorded for 496 of these. Of these, there were baptisms of children only, at Manguenzo and Guenga, totaling 121 baptisms in 1774 and 71 baptisms in 1775.

As in the earlier article, he combined two registers to get a larger number of individuals and a wider age range. Recalculation of his ratios left questions: his Chart 2 (p. 410) conveys no clear reason to prefer Model South level 4. His high ratios oL1/oL5 (.30 for females, .28 for males) imply rates of attrition too high even for level 1. His ratio of males to females MoL5/FoL5 = 177/206 = 0.86 is less than any of those from the tables. At level 1,East = .88, West = .92, North = .92, South = .97. As in his 1977 study, Thornton considered various regional models, but all of those he considered shared a common assumption on overall mortality and the rate of net population growth: that is, Level 4 or an expectation of life at birth of 27.5 years, with a net annual population growth of 7.5 per thousand.

Table 5.2 indicates the convention that Thornton followed in assembling results from separate baptismal registers into combined age pyramids intended to represent the population of young children in a given region. In this case, he combined baptisms recorded at three places: Papela (14) in 1775, Manguenzo and Geunga 192 (1774 & 1775), Ganza 118 (1775).[84]

Table 5.2. Assembling Baptismal Records into Age Pyramids (Thornton)
Source: Thornton (1978)

	Bap. 1774	Bap. 1775	Pop. 1775
[192-71=121]	121 tot.	71 tot.	
	38 age 0	42 age 0	42 age 0
	83 age 1+	29 age 1+	38 age 1
			29 age 1+
			83 age 2+

There remain questions on exactly how Thornton combined 1774 and 1775 figures: did he subtract a year from 1775 cases (as he says) or add a year to 1774 cases? Or leave them as is?[85] In any case, from such compilations Thornton developed an age pyramid for children from birth to age 10 at Manguenzo, as shown in Table 5.3.

Thornton then used this population pyramid as a basis for estimating total population of the Manguenzo region. As it happens, his population estimates include an error because he selected incorrect numbers from one of the tables he was reading, so that his estimate for the

[84] "However, I have deducted one year from all the ages recorded for 1775 [for Manguenzo-Guenga], so as to have a distribution reflecting the age of all children at the time that the priest first visited them"(p. 408). "In fact, this has not altered the data much, since over two-thirds of the baptisms recorded for both towns in 1775 were of children under one year of age, and clearly born between the two visits of the priests (of the 71 baptisms at M-G in 1775 46 were under one year of age." (p. 408)

[85] We need a general answer to how one may approximate a population by sampling from it at successive moments separated in time.

population of Manguenzo is given as a lower level than it should have been.[86] This error, however, does not affect the argument of the paper on basic demographic rates for Manguenzo.

Table 5.3. Age Pyramid Developed from Baptisms at Manguenzo
Source: Thornton (1978), 409

Age	Females	Males
9		
8	6	9
7	1	5
6	14	8
5	18	17
4	21	17
3	32	29
2	39	42
1	52	39
0	62	50

In a useful exploration of an additional issue, Thornton shows the relevance of baptismal records to the question of polygyny. Thornton reports that "only 54 of the 507 families visible in the register were actually polygamous." Of these 46 were cases of one man with 2 wives, and the maximum number of wives married to any man was 4.(Thornton 1977b, p. 411) Thornton concludes that plural marriage is just enough to take up the 10% surplus of females among children. Partners to marriage: 507 men, 570 women. Thornton notes that there may have been polygamous wives without children young enough to baptize, and there may have been unmarried young men. Only one woman was listed as a slave, and she had a daughter with father unknown – the only recorded case of birth outside marriage at Manguenzo.[87]

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[86] From model life table, Thornton estimated total pop, by taking his FoN1 and multiplying by To/FoL1, and same for males. His results: females 62x100/4=1550; males 50x100/3.96=1263; total 2813.

My check of his results:
F: 62x2750000/84023 = 2029
M: 50x2700735/81949 = 1648. Total 3677.

Thornton's error: he used To/oL1 ratios for level 1, which are 0.4 and 0.39 respectively; for South level 4, these are 0.31 and 0.30 respectively.

For model West, level 1
F: 62x1/76239/2000000=1626
M: 50x1/71893/1803445 = 1254. Total 2880.

For model East, level 1:
F: 62x1/70454/2000000=1760
M: 50x1/64112/1742500=1359. Total 3119.

[87] Review:

1. I must check his combination of '74 and '75 figures.
2. Model South level 4 is not the best fit. Too bad he gives no comparisons, no selection criteria.
3. Level 1 seems indicated, and models West and East seem better than South.
4. His total population figures are mis-calculated, but his 2 errors tend to cancel out.
5. He assumes no migration – seems unlikely.
6. His ratio of polygyny is a low estimate, as he implicitly notes.

In sum, Thornton's efforts at collecting and analyzing baptismal records and other demographic documents for precolonial Africa were a valiant attempt to locate primary data on population characteristics. The first problem with this approach is the scarcity of these documents, and the scattered nature of such documents as exist. The second problem is that, because of the complex interdependence of many demographic variables, documentation on a single variable such as baptisms, while it puts certain limits on overall demographic characteristics, is generally not sufficient to enable estimation of a full set of population characteristics—population numbers by age and sex, plus rates of fertility, mortality, and migration. The third problem is that the available documents must nevertheless be analyzed in a precise and comprehensive fashion. It is not surprising that there would be a few errors in setting up the analysis and in completing the calculations in Thornton's work—such work always needs to verified by collaborating scholars.

We thus are forced to acknowledge that little progress has been made in determining rates of birth and death in precolonial Africa. A variety of strategies can be considered for addressing this indeterminacy, and all of them should be pursued. One approach—the least dependable, yet one that cannot be ignored—is simple guesswork. Another approach is to seek out well-documented populations at other times and places which, arguably, might have had similar ecological and health conditions, and for which the demographic rates can be used as proxies for African rates. Yet another approach is to dig deeper into demographic theory and find whether there exist relationships among demographic variables that make it possible to estimate a wider range of parameters from the scanty evidence now existing. Finally, we must continue to seek out additional data, either from sources now unknown or through innovative analysis of sources that are already known. Of all these strategies, the latter one is surely the most promising.

Vital Rates as Affected by Migration

We turn now to the parallel but more complicated question of identifying the demographic rates of migrating African populations in precolonial times. These rates include age- and sex-specific rates of capture; rates of partition among those to be held within Africa and those to be exported; age-specific rates of mortality at succeeding stages of migration from capture to settlement.

Angola. Here again, John Thornton showed imagination in locating and investigating documents from West Central Africa under Portuguese influence with potential to shed empirical evidence on demographic patterns. In this case, he retrieved summary results from Portuguese censuses of Angola for the years 1777 and 1778 that had been published in an early twentieth-century colonial report.(Thornton 1981b.) The reported results broke the population down not by region but by age, sex, and free or slave status. Thornton chose not to report the numbers of persons but rather the percentage of each total population that was included in various age groups. He then compared the calculated proportions with the proportions of age groups in a standard model population – virtually the same population structure as that which he assumed

7. Caldwell's assumed mortality rates, with eo of 20-22 years, seem consistent with these data. See UNESCO and maybe CJAS.

was applicable to Kongo populations in the articles described in the preceding section of this chapter.

The results of his analysis, while open to correction on a number of points, clearly show that the Angolan populations described in the 1777 and 1778 censuses had undergone substantial migration—in particular that large numbers of men were missing, almost certainly because they had been sent overseas as captives. Further, the proportions of male and female slaves showed that there had been a particular emphasis on obtaining females slaves of reproductive age, and that the slave population was clearly younger than the free population, again reflecting the number of slave women in their reproductive years.

Table 5.4 reproduces the table in which Thornton summarized evidence from the censuses. The second column includes the proportions by age as they appear in the Coale and Demeny Model South level 4 (expectation of life of 27.5 years), with an implicit net growth rate of 7.5 per thousand per year. In the final column of the table we have added data from a different and arguably more relevant model population: Model South level 2 (expectation of life 22.5 years) with an implicit net growth rate of 5 per thousand per year.

Table 5.4. Angolan Age Structure, 1777 and 1778, after Thornton

		Census figures (% of total population)				
	Model Level 4, %	Slave 1777	Slave 1778	Free 1777	Free 1778	Model Level 2, %
Age (female)						
0 – 7	20.0	17.3	19.4	18.7	19.1	19.3
7 – 14	15.5	16.1	16.2	22.4	22.6	13.7
Below 14	35.5	33.4	35.6	41.1	41.7	33.0
14 – 40	41.0	52.5	51.3	46.3	45.3	46.6
Below 40	71.5	85.9	86.9	87.4	87.0	79.6
Age (male)						
0 – 7	19.9	22.8	23.3	19.0	27.1	
7 – 15	17.8	23.3	26.1	20.7	29.8	
Below 15	37.7	46.1	49.4	39.7	56.9	
15 – 60	56.7	47.5	44.6	48.3	25.3	
Below 80	94.4	93.6	94.0	88.0	82.2	

In comparing the various age groups, Thornton noted that one of the populations reported—for free males 15 to 60 in 1778—was exceptionally low and probably represented an error in transcription or publication.[88] Aside from that, he was able to show that there was a relative

[88] Indeed, it has been possible to confirm this error, since the addition of a single missing digit to the population figure for free males 15-60 resolves the whole discrepancy. Thornton addresses the problem by simply leaving free males in 1778 outside of his analysis, which was an adequate step in this case.

surplus of females and a relative shortage of males, and that this pattern was consistent with the departure through enslavement of numerous young or young adult males. Thus the study overall succeeded in using a cross-sectional study of settled population to demonstrate the underlying importance of migration, both in the movement of males out of the region and in the movement of both males and females from free status to slave.

Populations in West Africa. In yet another study, Thornton sought to generalize the results of his three articles discussed above to propose estimates on the question of whether African societies would have been able to avoid decline in population while losing large numbers of people to enslavement.(Thornton 1981a.) The results of his general analysis have been discussed in Chapter 3, and need not be discussed in much detail here. The analysis was made both vague and complex by the attempt to include population density as a central variable. In addition, Thornton made assumptions that tended to minimize the negative effects of slave trade: in particular he neglected mortality in the course of enslavement and he assumed a level of overall mortality that turns out to have been too low. Nevertheless, his assessment of the impact of enslavement on Africa was one of the more thorough efforts, and it had the advantage of noting that West Central Africa was the African region most readily susceptible to overall population decline as a result of enslavement.

Mortality, Fertility, and Age Structure for Migrating Populations. The average crude mortality in the Middle Passage was well over 15% of the captives in the seventeenth century, it averaged about 15% in the eighteenth century, and it declined to an average somewhat above 10% in the nineteenth century.[89] Two elementary points on this statistic are worthy of emphasis. First, when converted from a per-voyage basis to a more standard mortality per unit time, the figures may be analyzed more usefully. That is, since the average voyage across the Atlantic required two months, one can see that Middle-Passage mortality, if sustained for a full year, might have risen to a figure six times as high—that is, if sustained and calculated on an annual basis, such mortality would have resulted in the loss of the great majority of the captives embarked. Second, mortality was a schedule, not an across-the-board rate: its levels varied by age and sex. As a result, it is important to know the varying rates of mortality by age and sex, and to know the age and sex composition of the captives themselves.

While mortality in the Middle Passage is known in considerable detail, captive mortality in Africa (presumably the more significant factor) remains shrouded in mystery. Joseph Miller's study of Atlantic slave mortality notes two categories of causes of deaths in the Middle Passage—illness before boarding and conditions on board—and argues that the former was the main cause.[90] This argument implies a relatively high mortality in the later stages of captivity within Africa, although Miller implicitly assumes a low mortality in the initial stages of captivity. Perhaps the initial mortality was low for those who were kidnapped and high for those captured in war.

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[89] These rough proportions, calculated from a number of individual voyages, can be confirmed through review of the *Slave Voyages* dataset.

[90] Miller, "Mortality in the Atlantic Slave Trade." For a discussion of whether Miller would have benefited by using regression analysis on his data, see Cohen and Jensen 1982. And Miller (Mortality), 331 – 336.

Most figures on the ages of enslaved Africans must be viewed with suspicion, because different observers used varying age categories, and because of Europeans' notorious inability to judge African ages. On the other hand, numerous estimates of slave ages are available, and the question of the age distribution of slaves is important to a general assessment of the impact of slave trade. The proportion of children in the Atlantic slave trade was generally lower than that in the African populations from which they were drawn; in a sample population, children of ages 0-14 were 34% of the initial population; they were 26% of the Captives and 20% of the New Exports. Recorded proportions of children in groups of slave voyages range from 7% to 50%, but average 25%.(Manning 1981, p. 517)

An analogous issue awaits us at the other end of the age range. Ships' records almost never list old slaves, and this has tended to create the impression that persons over 40—or even over 30—were virtually never exported as slaves. But it is likely that were more New Export slaves of advanced age than is commonly realized, because of considerations at each step of the trade. First, old persons were a sizeable part of the population. Since African slave buyers had limits to their demand for such slaves, and since European purchasers did need to fill out their cargoes, a price could be found at which older slaves would be purchased to cross the Atlantic.[91]

Net Growth Rates

Net growth rates depend in a complicated fashion on the underlying schedules of age-specific fertility, mortality, and migration. While observed populations appear to have relatively stable rates of net growth, that does not mean that there exists a neatly determinative relationship among net growth, fertility, and mortality. For this reason, it is very difficult indeed to work from a small number of baptism figures and to project, in order, the birth rate, the overall population structure, and its net rate of growth. Thornton's effort to maximize the value of existing documents on African population simply could not hold up without a much more thorough demographic analysis and without additional information of some sort.

At present, therefore, the best answer is that Thornton's efforts have given us no information at all on population-level fertility, mortality, or migration—all of which would be necessary in order to develop estimated net population growth rates out of his data. (Reconsider and expand)

As a result, the best available approach is to apply a range of hypothetical rates of fertility, mortality, migration, and net growth. At present it is the statistical, rather than the empirical approach that has the best chance for yielding advances.

Fluctuations in rates. Consider fluctuations in rates because of drought, famine, epidemic, war, and other causes. What range for the fluctuations? Migration too is tied up in fluctuating rates of birth, death.

Conclusion

[91] [Include my estimates of age distribution elaborated from Postma's figures for the "Hester Coningen."]

While populations may be described in considerable cross-sectional detail through attention to the numbers of persons they include, the analysis of population change requires information on vital rates. That is, populations must be described not simply as totals but by age and sex and with information on births (by sex and noting the age of mother), deaths (by age and sex of the decedent), migrants (by age and sex), and rates of birth and death among migrants – all of these as they varied over time. This chapter's survey of available evidence on precolonial vital rates leaves us with some advances but with a need for much more evidence in order to reach the detailed understanding of African population and migration that is desired.

For each of the key vital rates, we have found that it is possible to exclude many values as theoretically or empirically impossible. But the range of values that remain within the realm of possibility is such that it remains difficult to make specific demographic projections. [Add a specific set of C&D tables that are admissible for Africa in this era.] Mortality was high in precolonial Africa, higher than often assumed. Fertility was high as well, but only high enough to go just beyond mortality and bring modest rates of population growth. These broad statements about fertility and mortality, to the degree that they can be sustained, are nevertheless long-term averages. On the other hand, we know from demographic records that short-term fluctuations show up often and represent an important overall factor in demographic evolution. Because the evidence is not stepping forward to answer our questions in a straightforward way, we must turn to a search for stronger methods that will draw more out of the limited evidence.

Chapter 6

Migration: Enslavement within sub-Saharan Africa

Reports on Enslavement: Twentieth to Seventeenth Centuries
Estimates: Northern and Eastern exports of captives
Modeling Enslavement for the Nineteenth Century

Enslavement within Africa is thought to have been significant over time, and especially in the nineteenth century. Yet it has almost never been part of the formal analysis of African population change, especially not at a continental scale. This chapter addresses the scale of continental enslavement within Africa from three perspectives: through an interpretation of long-term changes in the history of slavery, through a review of the published literature on slavery within Africa, and through systems of modeling and quantitative estimation.

A Long-term Interpretation

Reports on enslavement have been scattered, and the efforts to pull together the historical and anthropological literature on African slavery, while impressive, still fall short of being comprehensive.[92] But a long-term and comparative view of the process makes clear the recurring patterns of development in slavery. The process began with the small-scale and episodic enslavement that has occurred in many if not most human societies. This was slavery beyond the law, sustained more by the individual power of the captors than by any ongoing consensus within the social order. Occasionally, there developed a continuing demand for captives because of a concentration of wealth and power among certain strata—the eastern Mediterranean and southwest Asia provided such centers on a recurring basis from the time of the Akkadians. In these centers, the distinction between free and slave became a core element of law, rather famously in the Code of Hammurabi.[93] Regions at the fringe of these centers, drawn into furnishing captives, were drawn by the same process into holding captives for local use—and with this expansion came into being additional systems of law recognizing slavery. For the regions providing some captives and exploiting other captives, there sometimes arose a stage in which slavery became a mode of production: in this case, the primary demand for slaves was now within the region. Systems of law then changed to ensure more hierarchical relations. With the inevitable decline of slavery (for instance through the periodic collapse of imperial systems), there developed systems of slavery without slave trade: in this situation, almost no new slaves

[92] Orlando Patterson (1980?) provided a worldwide survey of slavery based on the Human Relations Area Files, though these concise records did not allowed for a detailed investigation of slavery in each society documented. Plus Miers and Koytoff, Robertson and Klein, Miers and Robers, Campbell volumes, E Af book.
[93] Hammurabi citation.

come into the region, but surviving slaves are kept in subjection. The legal and institutional system again adjusted—for instance, to provide more support for the birth and nurture of slave children. Finally, there arose situations of post-slavery, in which the economic and legal conditions of slavery had been abolished but in which social stigma still bore heavily on former slaves and their descendants.

Thus for Africa, in times before the fifteenth century, two patterns of enslavement affected the continent. First, and presumably throughout the continent, local systems of hierarchy and dependency had long existed and appear to have expanded in the early second millennium CE. This pattern would have brought the enslavement of a small number of people, especially as war captives, and would have brought a larger number of people into relations of dependency on others of higher rank in their own societies. Second, the relatively well developed systems of slavery in the Mediterranean and southwestern Asia, which had persisted at varying levels of intensity from the third millennium BCE, brought about the capture and export of Africans into those systems and also encouraged the expansion of slavery along the Sahara fringe, the Horn, and the Swahili coast. This interpretation contrasts rather sharply with that of John Thornton (1992), who gained wide recognition of the argument that slavery was widespread in sub-Saharan Africa before the sixteenth century.

In the African experience of enslavement from the sixteenth to the twentieth century, most regions went through all of the above processual steps, and all of the steps were tied to changes in slave trade within and beyond the continent. Northeastern Africa and the Maghrib had been in contact with the commercial economies of the Mediterranean and Arabia, and had long supplied modest numbers of captives. As a result, parallel institutions of slavery developed and persisted along the northern savanna and in the Horn. The Atlantic slave trade, beginning in the fifteenth century, expanded steadily and had exceeded the trans-Saharan slave trade in the late seventeenth century. Indian Ocean slave trade expanded from the thirteenth to the sixteenth century, declined for a time, and then expanded from the late seventeenth century.

This steady process of expanding enslavement along Africa's coasts—and across the Sahara—built up a related process of modification of African populations. For northern Africa and the Red Sea, most of the captives sent abroad were female. As a result, those remaining at home in northern and eastern Africa were dominantly male. In these regions, from which females left in relatively large numbers, the slave-descended population grew more slowly than in the Atlantic hinterland. For the western coast and the southeast coast of Africa, since most of the captives sent abroad were male, most of those held in Africa were female. As a result, those coastal populations came to include increasingly large numbers of females in servitude. In these dominantly female populations, the number of people of slave ancestry (through their mothers) grew steadily larger. The relatively high demand for female slaves meant that, among captives sent overseas, females were likely to have come from close to the coast, while males might have come from the far interior.[94]

Enslavement and its demographic impact are known to have been at a high level for many African regions in the nineteenth century. While the export slave trade across the Atlantic

[94] The difference was that male captives taken in the interior could only be sold for a good price by sending them to the coast, while female captives would sell to a nearby purchaser for a high price.

ended in the 1850s, exports across the Indian Ocean continued into the 1890s and exports to the Sahara and North Africa continued to 1900. The retention of captives within sub-Saharan Africa, long a by-product of slave exports, grew as a proportion of total enslavement and continued in some regions well past 1900. The flows of captives included those from the West African savanna to Saharan oases, the enslavement of people from the periphery of the great West African states of the Sokoto Caliphate and the empire of Samori, and the settlement of slaves along the routes from the Upper Congo and Lake Malawi to the Swahili coast. The task of assessing these regional flows and the overall magnitude of this nineteenth-century forced migration is intractable, and few serious efforts have been made at quantifying it.(Inikori, "Introduction"; Manning 1981; Lovejoy 1989)

The analysis of this book begins in the time when enslavement was expanding throughout Africa, especially because of growing external demand, and continues up through the near-complete destruction of slavery in the twentieth century. The volume of external slave trade is the most systematically documented measure of the changing process of enslavement within Africa. The reader is encouraged, first, to keep track of volumes of external slave trade and, second, to seek out links between external slave trade and enslavement within the continent.

In analyzing the process of African enslavement, our approach focuses not so much on its beginning as on its most dramatic expansion and its gradual decline. It took until the nineteenth century for the next and crucial transformation in enslavement to emerge. On one side, the continued high Atlantic demand came to be complemented by expanded demand from Egypt, Arabia, and the Indian Ocean. On the other hand, leading African social strata came now to rely on slavery to sustain their economic and social systems. To an extent, this expanded African slavery fed off demand from the world market—as with peanut culture in Senegal, clove plantations on the Swahili coast, and perhaps even leather goods in the Sokoto Caliphate. Mostly, however, it was a set of relatively autonomous regimes that built wealth through rapacious seizure and exploitation of labor – in the Merina kingdom of Madagascar, in the states of the Upper Niger, along the roads from the Indian Ocean to the Congo basin, and in the isolated but densely populated kingdoms of the Great Lakes. So much attention has been focused on African slaves as victims that not enough attention has focused on why African power-brokers chose to expand enslavement in the nineteenth century. It remains a curious issue, in that the increasingly slave-reliant regimes were substantially "autarkic," to use the term proposed for the Merina Kingdom of Madagascar by Gwyn Campbell (2005). Not all African states or societies involved themselves in this massively expanded system of slavery, but it was difficult to avoid. The recurring pattern of African leaders seeking to oppose enslavement, sometimes with significant short-term success, but then finding their regimes drawn relentlessly into active support of enslavement, slave trade, and slave economies.(Barry, Akinjogbin, Balandier, Fisher, Fernyhough), others. Benin was most successful, but after two centuries relented and joined slave trade (Ryder). With these regimes, Africa reached a peak in enslavement far different from any previous conditions.

There was one more stage to African slavery, which may be labeled "slavery without slave trade." It lasted a surprisingly long time—from as early as the 1870s to as late as the 1930s. As European powers seized control of African lands, mostly between 1885 and 1905, the wars of enslavement came to an end. Slavery changed greatly in that many of the enslaved ran away, while others were able to negotiate new rights within slavery, without having to run. Still, the

majority of the enslaved remained enslaved—only by the 1930s had the number of slaves declined to a small proportion. Again the laws and institutions changed: because few newly enslaved were now available, prices of adult females and children of both sexes shot up; food supplies and working conditions for slaves improved significantly. This system of "slavery without slave trade" lasted from roughly the 1880s to the 1930s in much of Africa, after which slavery lost its economic but not its social significance. This last half-century of African slavery was comparable to antebellum slavery in the United States (1808 – 1865), to the late stages of British Caribbean slavery (1808 – 1838), and to Cuban and Brazilian slavery from 1850 to the 1880s.[95] Slave mortality declined sharply in this era, but the oppression of slavery remained an important social fact. Similarly, the conditions of African ex-slaves and descendants of slaves, in the period since the 1930s, may be compared profitably with the experience of New World ex-slaves and slave-descendants in the decades after abolition.[96]

In its review of the literature on the character and extent of enslavement in Africa, this chapter reports on a range of primary and secondary descriptions of enslavement, by region and over time. This impressionistic survey is organized by region and by century from the twentieth back to the seventeenth centuries. It is to seek out reports that provide a basis for estimating rates and composition of enslavement and, in consequence, numbers of persons enslaved and held in slavery in African regions over time. The overwhelming majority of reports on slavery and enslavement in Africa were written by people new to the continent and relatively new to the languages and cultures about which they wrote. From the sixteenth to the eighteenth century these were primarily European mariners and merchants, as well as some religious officials; in the nineteenth century they came to include scientific explorers, religious missionaries, and diplomatic officials. At the turn of the twentieth century these writers came increasingly to be officials of European colonial regimes; later in the century anthropologists and other social scientists added their writings. African writers were few in number in the eighteenth and nineteenth centuries, and became numerous only after the end of colonialism in roughly 1960. Assessment of the qualitative literature on African enslavement therefore requires thorough attention to the background and approach of each individual author as well as to the changing social situations about which they wrote.

Reports on Enslavement: Twentieth to Seventeenth Centuries

Twentieth Century. As European empires established their colonial regimes in Africa, they sought out information on the populations suddenly under their control. The scholarly field of anthropology was just being established, and it took until the 1920s before academic anthropologists came to Africa in any numbers. Initially, therefore, colonial officials who had spent several years in Africa took up the task of visiting and describing the various ethnic groups and states across the continent. Their initial reports ultimately became books that have since become central to the understanding of African ethnology. The officials, while commonly lacking in formal academic training, had the advantage of having considerable experience on the ground, often including a good knowledge of the language of the people under study – that was facilitated, not uncommonly, by intimate relationships that the officials set up with African women. Maurice Delafosse, in French West Africa, was in addition a scholar with good

[95] Venezuela, Colombia and Peru from the 1820s to the 1850s, Arabia from 1900 to the1930s, and others.
[96] See, for instance, Butler (200x).

knowledge of Arabic language, and he published critical editions of major Arabic texts in addition to his anthropological and historical survey of the upper Senegal and Niger valleys. Louis Tauxier in Ivory Coast, Auguste Le Hérissé in Dahomey, P. A. Talbot in the Ibo and Niger Delta regions, R. F. Rattray in Asante—these and other such authors provided detailed descriptions of African societies in the early twentieth century, with interpretations of the late nineteenth century. On the other hand, their reports were biased by their own imperial preconceptions and by the informants on whom they relied – generally senior men who had survived the transition to colonial rule, and who gave self-serving interpretations of their own societies, so that alternative interpretations often failed to be included in the published record.

Scholarly anthropologists carried out descriptions of African societies from the 1920s to the 1960s. Most commonly, these scholars focused on small and disaggregated societies, where there government-anthropologist predecessors had focused on large states. Outstanding among them was E. E. Evans-Pritchard, who studied with Bronislaw Malinowski and C. G. Seligman at the London School of Economics, and who conducted fieldwork in the upper Nile among the Azande (from 1926) and the Nuer (from 1930).[97]

In a third wave of writing about African social orders, academic historians and anthropologists in the era of postindependence African Studies gave summaries and critical reviews of the earlier studies, colonial documents, and field study of African societies. Sources: Official ethnologists; Miers & Kopytoff; Miers and Roberts.[98] EXPAND

Nineteenth Century. For the nineteenth century we have a relatively strong set of primary and secondary sources. Especially in the last half of the century when enslavement was at its highest level, European travelers visited and wrote about many sections of the continent. The travels of the missionary David Livingstone are best known in this regard; also well known are the travels of John Henning Speke in East Africa and those of Richard Burton in East Africa, West Africa, West Central Africa, and Arabia. Among the most detailed reports are those of Gustav Nachtigal and Heinrich Barth, who spent years in residence in the central savanna, east and west of Lake Chad.

Further, twentieth century scholars – anthropologists first and historians later – have collected documents and oral traditions that amplify the details recorded by earlier writers. The growing number of African-born scholars among these investigators has helped to clarify the perspectives within African societies past and present.[99] EXPAND

Eighteenth and Seventeenth Centuries. Sources 18th: Law, Northrup, Miller, Curtin & Searing on Senegambia, Roberts on Bambara
Sources 17th: Kea, Rodney, Vansina, Balandier, Brooks, Thornton, Olivier de Sardan.

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[97] Evans-Pritchard on Zande and Nuer. For the Nuer his approach was cross-sectional and contemporary, yet these were among the peoples who had undergone slave raids for not only centuries but millennia, and whose social structures were arguably transformed by that experience.
[98] Miers and Kopytoff, Miers and Roberts.
[99] Sources: Secondary: Meillassoux, Klein, Inikori, Lovejoy, Cordell, Miller, Cooper. Primary: Livingstone, Park, travelers to every region. (Include political economy of slavery in Africa: Meillassoux, Miller, Manning comments on each.) Mason, Buxton, Nadel, Person.

EXPAND – note there are no descriptions of 18th or 17th centuries with such huge numbers of enslavements, except perhaps Angola.

Directions of Captive Flow. To model enslavement in detail, and to account for the empirical estimates of enslavement drawn from the previous section of this chapter, it is necessary to catalog the directions of flow. Tables 6.3 and 6.4 show the regions among which captives are assumed to have flowed during the nineteenth century. Table 6.3 illustrates these assumptions for five slave-trade regions of West Africa (Senegambia, Upper Guinea, Grain Coast, Gold Coast, and Western Sudan) and for the sub-regions within them. The dark cells on the diagonal indicate flows of captives within a given sub-region. The shaded cells indicate that captives moved from the region listed on the vertical axis to the region listed on the horizontal axis. Thus, while Guiné Bissau did not send captives to Gambia, Gambia did send captives to Guiné-Bissau.

Table 6.3. Directions of Continental Captive Flow.

(Vertical axis: region of out-migration. Horizontal axis: region of in-migration)

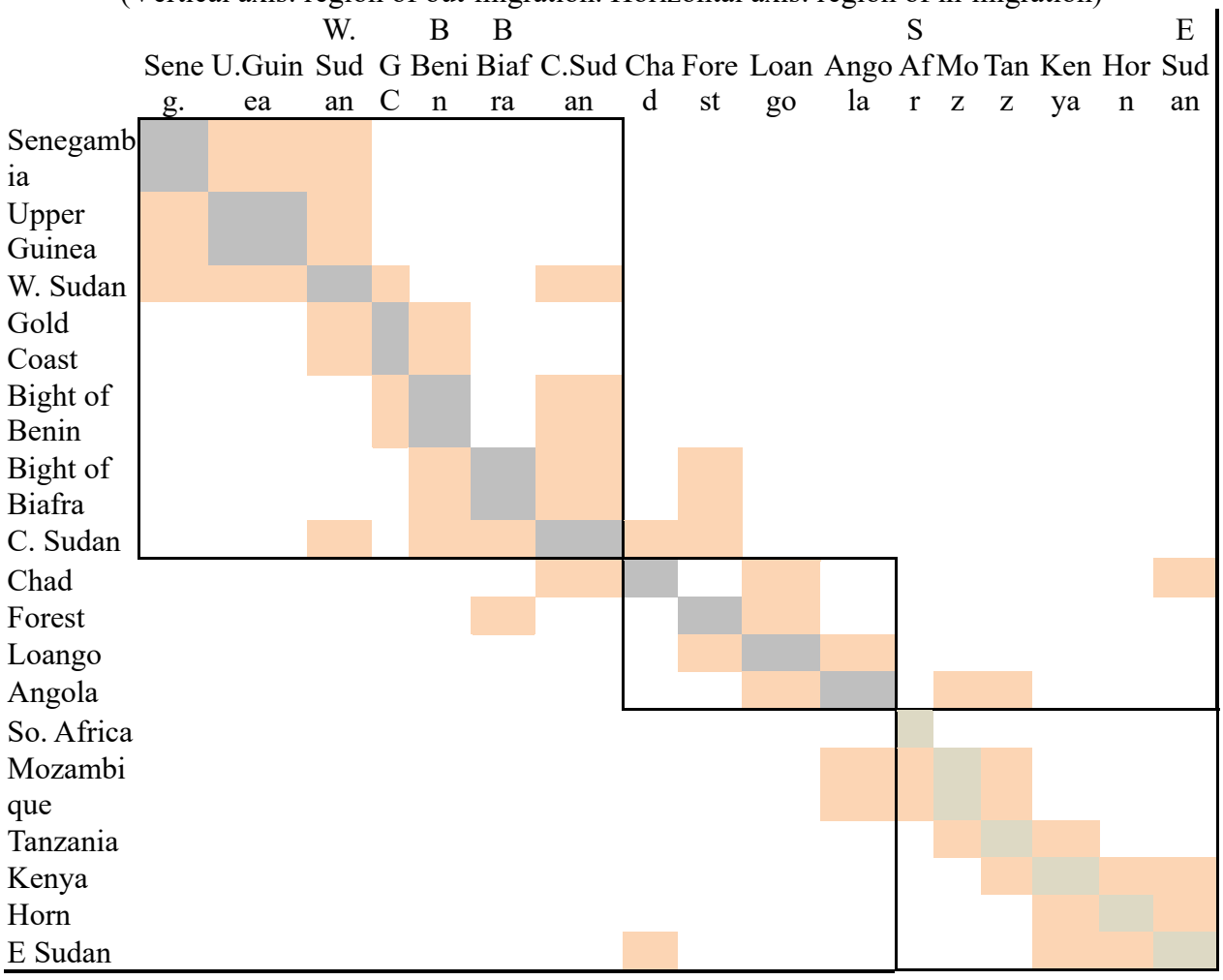

Table 6.4 shows a similar set of relationships at a closer scale. Rather than show the major slave-trading regions for the whole of the continent, it shows the sub-regions within these

major regions (from one to four sub-regions per region), and does so only for a portion of West Africa. Again, the list on territorial names on the left indicates the territories from which captives are being sent out; the list of names on the top indicates the receiving regions. Naturally, continental slave trade was primarily among regions located adjacent to each other, but the specifics of economy, state, and population – rather than sheer proximity – determined the direction of continental slave trade.

Table 6.4. Directions of Captive Flow for West African sub-regions.
(Vertical axis: region of out-migration. Horizontal axis: region of in-migration)

	Maur	Senegal	Gambia	Guine B	Guinee	Sierra L	Liberia	Mali	Upper V	C-I	Akan	N GC	TVT	Togo
Mauritania														
Senegal														
Gambia														
Guine-Bissau														
Guinee														
Sierra Leone														
Liberia														
Mali														
Upper Volta														
Ivory Coast														
Akan														
N. Gold Coast														
TVT														
Togo														

Conclusion

As Portuguese mariners visited African coasts from the mid-fifteenth century forward, they seized and enslaved Africans at various points, and gradually developed systems of purchasing captives to carry back to Portugal and the Atlantic islands. Some scholars have concluded that the ability of Europeans to purchase captives at many points of the African littoral shows that enslavement was widespread, and the that visitors bought only a small portion of those already enslaved.(Thornton 1992) On the other hand, the early Portuguese chose not to purchase captives in certain parts of the African coast, notably the Gold Coast, where they built Elmina Castle and focused on purchase of gold. Indeed, in the early sixteenth century Portuguese

merchants brought slaves from the Benin kingdom (of the lower Niger valley) to Gold Coast, and sold them in exchange for gold. This exchange suggests that slaves were not otherwise plentiful in Gold Coast. The complaints of African leaders about the expansion of slave trade—notably by the king of Kongo in the late fifteenth century and by leaders in Senegal during the sixteenth century—suggest that large-scale enslavement was an innovation and an unwelcome one.(Balandier (Kongo); Barry (Senegal)

The qualitative documentation on the level of enslavement in sixteenth-century Africa—both the primary documents of contemporary visitors and the secondary works of later scholars—conveys the impression that, while legal and social institutions of slavery and related sorts of social subordination clearly existed, the number of people in slave status was relatively small. The one great exception was the Songhai Empire, which arose in the mid-fifteenth centur to match the empires of the Mediterranean in scale, in military and economic power, and in the extent of its enslavement—until its sudden and near-complete collapse with the Moroccan invasion of 1591.

Militarization and enslavement seem to have grown somewhat in the seventeenth century, along with the expansion in slave exports, especially along the western coast of Africa—in Senegambia, Gold Coast, Bight of Benin, Angola, and even in Mozambique. During the eighteenth century, expansion in slave exports proceeded in periodic waves for various regions: the Bight of Biafra and Loango stood out [give decades for each]. For at least some regions, it appears that continental holdings of slaves expanded along with the wars, kidnapping, court proceedings and other activities through which captives were collected for export.(Manning 1990)

The continent-wide structure of external slave trade shifted from the late eighteenth to the early nineteenth century, and so also did continental patterns of enslavement. The relations of cause and effect can be argued in various ways, giving primacy either to the overseas or the continental factors. In the external slave trade, Atlantic trade peaked in the 1790s and declined thereafter in most of West Africa, but expanded in some parts of West Africa and especially in Central Africa; Indian Ocean slave trade expanded from the late eighteenth century, and North African (especially Egyptian) purchases of slaves grew at the turn of the nineteenth century. In continental enslavement, demand grew at much the same time in several parts of both African interior and coast. Most striking was the expansion of enslavement in the Great Lakes kingdoms, densely populated but far from the coast, even before the nineteenth century.

The Merina kingdom of Madagascar, which became a major slave-trading and slave-holding regime from the late eighteenth century, was an outstanding and conceivably paradigmatic example of this process. It may be representative of parallel patterns on the African mainland rather than, as usually portrayed, an exception. The Merina kingdom's "autarkic" expansion of slave production for an expanding royal household and associated elite strata—a local development that was somehow part of a widespread pattern—was mirrored in roughly contemporaneous developments in the Great Lakes kingdoms, Ethiopia, the Sokoto Caliphate, the Islamic states of the Upper Niger, Asante, Dar Fur, the Zulu kingdom, and the varying regimes of Mozambique. In these areas an in others, enslavement seems to have expanded even when slave exports declined, reaching the highest level ever. As a result, not only did the continuing high levels of export slave trade bring severe limitations and structural

transformations to African population, but the mortality associated with the increasingly high level of continental enslavement tended further to limit and reverse any tendencies of overall population to grow. The pattern was certainly destructive overall, yet brought wealth and power to expanding African elites.

The three models of continental enslavement documented in the latter sections of this chapter provide alternative hypotheses that can be compared with available data and their connections. The most extreme of them, Model 3, is proposed as the appropriate one for exploring the possibility that the Merina Kingdom may have been somewhat typical of the continent. The more detailed analysis of later chapters will address in greater detail these rough estimates of numbers enslaved, sent in various directions, and meeting early death in the course of these displacements, with attention to the age and sex composition of enslaved populations and to the changing experience of the enslaved over time.[100]

[100] For instance, the simulations of population change will trace details of the enslaved populations within Africa by accounting for the number of the enslaved surviving and the number of their offspring over forty-year periods as well as the proportion of the enslaved within African populations over forty-year periods.

Chapter 7

Analytical Models of African Population Change

The Model of African Population in general terms
The model in terms of crude rates
The model in terms of composition-specific rates
The composition-specific model in matrix terms
Migration Data: "Multiple Perspectives" and "Voyage-based" Approaches
Conclusion

This chapter encompasses the evidence and analysis of the previous chapters by presenting a general model of population change, accounting for fertility, mortality, migration, natural increase, and for other variables that affected the demography of Africa. The model provides a meeting place for empirical evidence (on African population, migrations of slaves and others), a set of well-known demographic correlations, fundamental hypotheses on historical change, and details of relationships among variables. We begin with the model in its most general and qualitative form, accounting for the full range of variation, and estimates of error and confidence levels in the historical data.

Secondly, and in fuller detail, we express the model in two contrasting sets of terms: crude rates and composition-specific rates. The model in terms of crude rates expresses demographic variables—mortality, fertility, migration, and net growth—as a proportion of the full population under consideration. In this approach we ignore subgroups in the population. The crude-rate approach is most obviously necessary when more specific data are not available. In addition, crude rates are of interest for linking numerous variables in a simplified analysis and for comparing populations over space and time. In this study, the crude-rate is central to analysis of the colonial period, 1890-1950, but is also used for earlier times. For the model in terms of composition-specific rates, we mean that populations are divided according to age and gender, and that each of those groups undergoes specific rates of mortality, fertility, and migration.. We express the composition-specific model both in terms of simultaneous equations and in terms of matrix algebra, as each of these approaches has certain advantages in exposition and analysis. We apply the composition-specific model especially for the period before 1890. In the present chapter we introduce each model in general; in Chapter 8 we discuss further characteristics of both models, including the calculation of error models within each.

Migration data require more detailed modeling, because of the great variations in quality of available data. At one extreme are instances where we have no information on migration; at the other extreme are a few instances were we have full details; and in between we may find a range of qualitative or quantitative data. Because we are focusing on quantitative estimates of migration, we have tried to incorporate the range of these cases into two categories: "synthetic" estimates of quantities of migrants; and "voyage-based" estimates, especially for the transatlantic

slave trade, where data of varying qualities have been organized in terms of voyages of ships. (Detailed characteristics of these migration models, including summaries of migration totals and of error margins, are presented in Chapter 9.)

The Model of African population in general terms

The purpose of the overall analysis is to estimate population size and growth for the African continent and its regions between 1650 and 2000 and to ensure that these estimates are consistent with what is known or best assumed about the dynamics underlying population change. In general, we define the populations under analysis according to four types of measurement: by time, by social status, by place, and by the environmental and social influences they undergo. We introduce the general model with concise descriptions of these four types of information, then turn to the model's statistical dimension.

First, in its temporal framework, our analysis and estimation starts from known recent populations and subsequently works back in time by decade, calculating populations for each year "ending in 0," assuming that the dynamics relating one decade to another are centered on the midpoint of each decade. Each population is assumed to have geographical and demographic limits. Within these limits, the principal demographic variables are the rates of fertility, mortality, and migration of the population, the total population at the start of each decade, and the change in total population from one decade to the next. We use a process of back-projection or "retrojection," using the midpoint population of a region in a given decade and a growth rate as a basis for estimating the midpoint population of the same region ten years earlier.

Second, the social categories into which we divide the people of Africa and the African diaspora are Free populations that lose some of their members into captivity, Captives (those recently seized and in process of transportation to their point of settlement), and Slaves (persons living in slave status, either having been captured or born into that status). In addition, some people in slave status manage to gain liberation, thereby achieving the status of free persons (or at least the status of ex-slaves). Figure 7.1 shows a simple characterization of this modeling of African and African-descended populations.[101]

Third, in its spatial framework, the analysis accounts for the entire African continent plus (in less detail) those regions beyond Africa that received African migrants. With the increasing availability of African regional and subregional data, it is now realistic to conduct the data collection and analysis at low levels of territorial aggregation rather than at continental or subcontinental levels.[102] Results analyzed at the level of colonial territories and sub-territories can then be aggregated to the levels of slave-trade regions, continental regions, and for Africa as a whole. Just as breaking down populations by their age and sex composition increases the

[101] In addition, and not shown in Figure 1, we also make racial distinctions in populations in Africa, since those identified as "white" or "Indian" were not enslaved in Africa. In Northern Africa, people known as "Arab" or "Berber" were generally not enslaved, though Arabs and Berbers of dark skin with sub-Saharan ancestry were sometimes enslaved; in addition, European captives were enslaved until the nineteenth century.

[102] When sub-territorial data are lacking for 1950 or 1960, they may be estimated by interpolation from sub-territorial data available for nearby years. This technique was used for Angola, Mozambique, and Sudan, for instance.

precision and accuracy of the analysis, so also does breaking down populations by relatively coherent sub-regions.

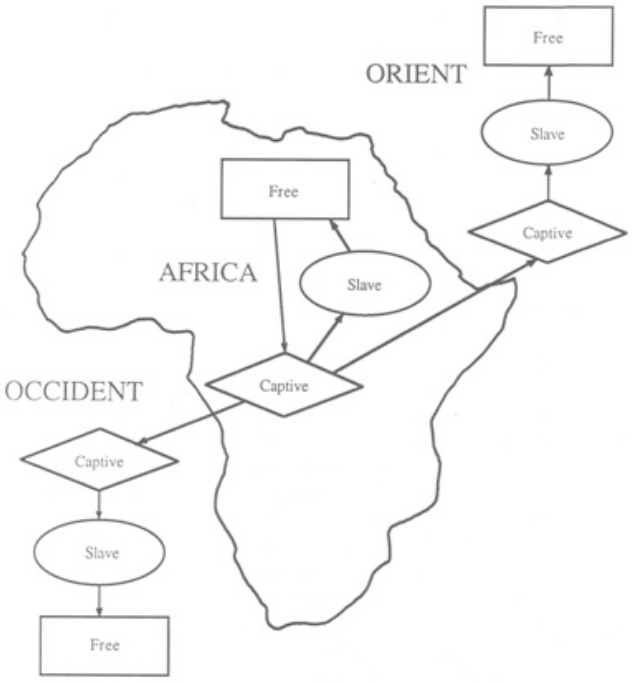

Figure 7.1. Populations in the slave trade

In the regional parameters of analysis, we have adopted the convention of relying on colonial and post-colonial boundaries, in attempt to work with consistent territories throughout the three centuries of the analysis. The territories are now organized into several types and levels. At the highest level, we identify the standard set of six geographical regions for Africa introduced in Chapter 1. At the next level, we identify 18 slave-trade regions for parts of the continent that exported slaves, plus six regions of the continent that did not export slaves (five for North Africa and one for Southern Africa). North Africa and Southern Africa are included in this analysis partly to achieve comprehensive estimates of African populations and partly because comparison of these data with other African data may improve the quality of estimates for all regions. The third level is that of colonial and national territories of the continent. But since colonial and national boundaries do not always fit the historical regions of slave trade, the fourth level consists of relevant sub-colonial territories and populations by race (see Figure 7.2). Thus, the northern portions of Gold Coast, Togo, Dahomey, and Nigeria are broken out from the southern portions of those territories, as the northern portions functioned as parts of the slave-trading system of the savanna rather than of the Atlantic coast. Similarly, Cabinda is broken out from Angola because its slaves were exported through Loango; Katanga is broken out from Congo because its slaves were exported through Angola. Further, for Mozambique, Lesotho, and South Africa, people labeled as Europeans and Asians, not liable to enslavement, are calculated

separately from those labeled as Africans and Coloured, from whom slaves were drawn.[103] In practice this fourth and lowest level of territorial aggregation – consisting of a mix of colonial territories, sub-territories, and racial groups within them – is the level at which data collection and analysis takes place.[104] The results are presented for colonial territories, slave-trade regions, and continental regions.

Figure 7.2. Slave-trade Regions of Africa.

For our spatial analysis, we rely on the same 66 regional subunits at every stage of the calculations, aggregating them in different ways to get colonial, slave-trade, and macro-regional totals. For the slave-trade analysis, African sub-regions are also defined according to whether their exports of captives went uniquely into the Atlantic market, uniquely into the trans-Saharan or Indian Ocean markets, or went to two of the three markets. While trans-Atlantic captives were dominantly male, trans-Saharan captives were dominantly female. Slave exports across the Atlantic and the Sahara for each decade are therefore be broken down by region of origin and also by sex, in order to project the impact of slave exports on the population of each region.[105] A

[103] For this reason, the African continental totals shown in Table 5 are lower by roughly three million than the totals in Table 1 and Table 4; the difference arises entirely from Southern and Eastern Africa.

[104] Data and calculations are processed at the level of individual cells, and then aggregated geographically for each time period. See Appendix ?? for specifics.

[105] Thus, captives taken in Upper Guinea were exported only across the Atlantic, captives taken in Senegambia were exported across both the Atlantic and the Sahara, and captives taken in the Western Sudan were exported in several directions – across the Sahara, to settlements within the Sahara, and across the Atlantic through Senegambia, Upper Guinea, and Gold Coast. Anticipating this procedure has reaffirmed the choice to subdivide the populations of Gold Coast, Togo, Dahomey, and Cameroon into northern and southern subgroups, and the division of Nigeria into its old regions of West, East, and North. (Similar adjustments are made for captives flowing in multiple directions from Chad, Sudan, Ubangi-Shara, and Mozambique.)

second problem in the accounting of slave trade is that of regions that exported few slaves or no slaves. Such regions included southeast Cameroon, Gabon, parts of Ubangi-Shari, Southern Rhodesia, Rwanda, Burundi, Uganda, and the Orientale and Kivu regions of Congo. So far we have included each of these regions within an adjoining slave-trade region; the alternative would be to make them into separate regions. Though these regions were not active in slave exports, analyzing their population growth is important, in order to include interpretation on whether their demographic rates were similar to or different from those of slave-exporting regions. Shona territories of Southern Rhodesia, for instance, seem to have avoided the slave trade of neighboring areas of Mozambique during the nineteenth century. Does that mean that Shona populations rose significantly in proportion to those of Mozambique during the nineteenth century? Life expectation seems to have been higher among the Shona; did their birth rates decline in compensation? We have tended to assume "natural fertility rates," which could not easily be adjusted, but this analysis of colonial-era populations offers an opportunity to reconsider that issue.[106]

Fourth, we seek to account for some of the many environmental and social factors that influenced the population of Africa, including persons in both free and slave status. Environmental changes included fluctuations in rainfall and occasional floods, droughts, famines, disease and health conditions. Social variables include effects of war and peace, security and insecurity, social hierarchy, economic boom and bust, and changes in technology. Depending on the situation, environmental and social variables may have exerted large or small influences on demographic variables. We have not been able to model these influences systematically but we have tried to sustain a discussion of them, at least for the colonial era. We seek to trace the effect of each socio-environmental variable on fertility, mortality, and migration. Especially for the twentieth century, some of these environmental and social factors have made their way explicitly into our estimations.

All of the data incorporated into this analysis—whether obtained from archives, from estimation by past authorities, or from current projections—have varying levels of precision and dependability. Therefore an important dimension of our approach is to use the most appropriate statistical and probabilistic techniques for assessing the dependability of individual data points and especially the overall degree of confidence readers may have in calculations combining large quantities of data. The 1950 populations with which we begin our analysis are known only to a certain level of precision; each decade of back-projection introduces a potential error into the calculation. We have sought to provide indications on the confidence intervals surrounding each of our demographic estimates, both for African populations and for estimates of captive migrations. In the latter, for transatlantic shipments of captive Africans—we have detailed yet incomplete data from ships' records. Data are entirely missing for about 25% of all those who crossed the Atlantic; for the other 75%, data range from crude counts of embarkations or arrivals by region to occasional details of composition and mortality by age and sex. Yet by using statistical techniques based on the patterns among the captives who are well documented, it is possible to obtain a detailed estimate of the number, origins, mortality, and destinations of those

[106] "Natural fertility rate" refers to the assumption that females were exposed without restriction to the risk of fertility. If they did not restrict their fertility, they could also not voluntarily increase their fertility. The assumption is plausible since African women commonly married early and remarried at the death of their spouses. But there may be reasons to revise this assumption: for instance, there have been arguments that slave women had lower fertility than free women. (Klein 1998).

for whom data are missing. As with back-projection, the estimation introduces a potential error, and it is possible to estimate confidence intervals surrounding the estimates of transatlantic migration of captives.

The combination of these four dimensions of change—time, social status, space, and environmental change, with confidence intervals attributed to all the data—enables our general model to portray biological and social reproduction of a population through the workings of fertility, mortality, and migration. For a stable and non-migrating population, the combination of fertility and mortality may yield a stable rate of natural increase or net reproduction. But African populations of the last several centuries have experienced high levels of migration—outmigration of captives and migrations of free people and slaves within the continent—so that stable rates of natural increase were rarely in force. More generally, biological reproduction is rarely left undisturbed: the nature and rate of reproduction is influenced not only by migration but by social and environmental variables.

In its most systematic implementation, our model would apply all of these considerations to each stage of the analysis, from 1650 to 2000. In practical terms, we apply the model in different ways at different times, in response to variations in available data and changes in historical situations. The general model, including its statistical procedures, is applied in somewhat different ways for each of four periods. The specific model for each period gives attention to the most important sort of change in each period, simplifies the model for ease of calculation where the data permit, and accommodates the relative absence of data at various times. As we have done consistently through this volume, we conduct the analysis and the estimates from the most recent time to the earliest.

For the period 1950 – 2000, we rely on aggregate figures for population size and growth of African nations as calculated by the United Nations Population Office, based on censuses and population surveys. We also draw on UN figures for aspects of the composition of these populations.

For the period 1890 – 1950, we estimate populations based on crude rates of growth as these are influenced by various social and environmental variables. This was the colonial era in which African territories were overwhelmingly under European colonial rule. There were virtually no systematic censuses of African populations in this era. We assume, however, that social conditions were stable enough – often under police control – so that socio-environmental factors influencing demographic variables can be analyzed through crude rates rather than through composition-specific rates. This approach, simplifying the analysis of each socio-environmental variable, makes it feasible to include a larger number of such variables in the analysis.

The period 1790 – 1890 was the period of the highest level of migration, combining both overseas and continental migration through slave trade. The analysis therefore focuses primarily on migration, and gives less attention to other socio-environmental factors. (Another way to say it is that the analysis focuses directly on levels of migration, rather than analyzing the socio-environmental factors that bring about migration.) The analysis of the number of captives sent across the Atlantic, based on empirical data but including estimation of missing data, relies on crude demographic rates for the captives. Similarly, the estimates of captive exports across the

Sahara, Red Sea, and Indian Ocean rely on crude rates of migration. For the continental slave trade, estimates (also in terms of crude rates) are made on the assumption that enslavement continued unabated when export slave trade declined. Nevertheless, the demographic simulation that links continental African populations to these migrant flows relies on a composition-specific analysis: specifically, age- and sex-specific figures for fertility, mortality, and migration. Overall, in this era, export slave trade declined while continental enslavement continued to expand.

For the period 1650 – 1790, the analysis is parallel to that for the period 1790 – 1890, but is simplified. The expanding overseas slave trade of this era is assumed to have brought a parallel and linked expansion of enslavement within the African continent. Age- and sex-specific rates of fertility, mortality, and migration are employed in the population estimates for this era, though they are linked to crude rates of migration outside of sub-Saharan Africa.

The Model in terms of crude rates

Crude rates of fertility, mortality, migration, or net growth may be calculated for an entire population. These are usually calculated as the rates of birth, death, migration, or net increase per thousand persons per year in the original population. (Crude fertility rates are usually calculated as the number of births per thousand females in the original population per year.). Crude rates take almost no account of the details of the population pyramid—the distribution of the population by sex and age.

Since we are analyzing African population by region and sub-region, we can estimate populations and crude rates of population change for 66 African regions and get an idea of the differences among them. This is the approach we take – while the individual populations are not broken down by age and sex, each population is assigned varying rates fertility, mortality, migration, and environmental and social influences.

Fertility. The crude rate of fertility F in a five-year period is the number of male and female births within that period divided by the mid-point female population in the same period, and is usually reported as births per thousand females:

$$F = b(t) / Pf(t)$$

For summation of rates of fertility and mortality, however, it is necessary to calculate fertility rates using the total population:

$$F = b(t) / P(t)$$

Mortality. The crude rate of mortality M in a five-year period is the number of deaths within the period divided by the mid-point total population in the same period, reported as deaths per thousand persons.

$$D = d(t) / P(t)$$

Migration. The crude rate of out-migration M in a five-year period is the number of out-migrants in that period less the number of in-migrants in the same period, divided by the mid-

point total population in the same period, reported as out-migrants per thousand persons. (Net out-migration will be negative in cases were in-migrants exceed out-migrants.)

$$M = (e(t) – i(t)) / P(t)$$

Net growth. The crude rate of net growth of a population P in a five-year period is the difference between the total population at the end of the period and at the beginning of the period, divided by the mid-point population. It is reported as net growth per thousand population.

$$G = (P(t2) – P(t1)) / P(t)$$

One may also write the crude growth rate as the sum of the crude rates of birth, death, and migration.

$$\Delta G = \Delta B – \Delta M + \Delta(M – E)$$

Another way that the crude growth rate is used in this analysis is to consider the change in crude growth rate from various causes, where the various environmental influences on the crude growth rate (both positive and negative) are summed to give the crude rate of net growth:

$$\Delta G = \Delta G1 + \Delta G2 + \Delta G3 + \Delta G4$$

These simple rates, while they mask the complex variations within populations, nevertheless give a useful indication of overall population patterns.

The Model in terms of composition-specific rates

Composition-specific demographic rates may be calculated with regard to age, sex, and status. That is, the demographic variables of fertility, mortality, and migration may be broken down in composition by age, sex, and status. Status can be broken down into additional sub-categories by ethnicity, religion, or occupation; with regard to slave status one may distinguish persons who are free, captive, slave, liberated, or slave-descended. In our analysis we prefer to use composition-specific data and rates when we have access to them through historical documentation or through known demographic patterns; we use crude data and rates otherwise.

The model approximates a continuous process, like most such models, and is expressed in terms of five-year age groups (Keyfitz 1977). All the populations exist at each moment; they change in size and structure in response to their various rates of fertility, mortality, and migration. The populations are the variables in the analysis. The numerous rates of fertility, mortality, and migration are taken as parameters.[107] The analysis consists of determining which parameters are most important, both theoretically and historically, in setting patterns of population change. In the conclusion I offer a simplified history of the slavery of Africans in terms of changes in these key parameters.

[107] The variables and the parameters are each matrices, with dimensions of age and sex: in this case, 2 sexes by 17 age groups (0-4 to 80+) .

Figure 7.3. Reproduction and migration in the African and Atlantic slave trades

In Africa and for Africans abroad, the broadest distinctions were among the free, slave, and captive populations. In Africa, the free populations were usually the largest, though in a significant number of instances -for example, the Western Sudan in the late nineteenth century- slaves outnumbered the free (Klein 1987). The free populations included those liberated either by manumission or by escape.

The captives, while always the smallest of the three groups, had sufficiently distinctive characteristics that they must be identified and analyzed as populations distinct from the slaves they became. Captives were people recently placed in captivity; they were in transit to their destinations or undergoing training and seasoning (socialization) prior to becoming productive slaves. In demographic terms, the mobility of captives and the extremely poor conditions in which they lived meant that their rates of fertility and mortality were far more unfavorable than those of settled slaves.

The same three broad categories—free, slave, and captive—apply to populations of African descent abroad. Here *abroad* means, primarily, the slave plantation colonies of the Americas, but it also refers to the significant numbers of slaves who were settled in North Africa and the Middle East, in the Sahara Desert, in the islands and littoral of the Indian Ocean, and in Europe. In each of these areas the captives were those newly arrived from sub-Saharan Africa fresh off the boat or the caravan, or undergoing the process of seasoning. The slaves dominated

the populations of African descent in these slave-importing regions. In addition, however there were significant numbers of free persons of African descent.

The demographic logic of the analysis takes the form of a multiregional, multistage process (Rogers 1985): multiregional because it addresses several geographical and social regions (i.e., African, New World, and Old World regions; free, captive, and slave populations within each region) , multistage because several populations undergo decrement both by death and by out-migration (through enslavement or liberation), and also because people may enter one of several populations either by birth or by in-migration.

Further, the path of migration from one region to another affects the outcome of migration, as migrants experience distinct patterns of fertility and mortality along the way—for instance, the heavy mortality of slaves during the middle passage across the Atlantic. In one sense, this amounts simply to adding more stages to the process described above. In another sense, however, it may be useful to think of the model as assuming *eventful* migration. The migration is assumed to be slow and eventful, rather than rapid, so that the path of the migrants and the events they undergo must be included explicitly in the analysis. This approach contrasts with that of many migration models, in which only destination and not the path of migrants is included; in effect, such models assume migration to be instantaneous.(Rogers 1998)

Within Africa, people are assumed to have migrated as a result either of enslavement or of its opposite, liberation. When a man freed his slave wife, the woman's status changed but she was not displaced physically. To utilize the standard analytical simplification, however, we may consider her change from the status of slave to that of a free person as a migration from one population to another. In the New World and other slaveholding areas abroad, migration similarly took place through absorption of the imported captives into the slave population, and through the liberation of slaves by manumission or escape. The liberation of slaves, in this version of the model, is assumed to be uneventful and instantaneous, in contrast to the slow and painful migration of captives.

Figure 7.3 focuses, for heuristic purposes, on the slave trade from Africa to the New World. It shows, in more detail than Figure 7.1, the various populations and their births, deaths, and migrations. The divisions we have made are as follows: Free persons in Africa are divided into Source and Captor populations, plus the Liberated; free blacks abroad are divided into the Liberated and the Free-born. Slaves in Africa are divided into the Enslaved (or first generation slaves) and the Slave-born (subsequent generations of slaves); slaves abroad are divided in the same way. Captives in Africa are divided among the Domestic captives (who are to become slaves in Africa) and the Transit captives (who are to be sent abroad). Once outside sub-Saharan Africa, the surviving Transit captives become Export captives and ultimately become Enslaved abroad.[108]

[108] For each population in Figure 7.3, one may catalog the sources of in-migration and the directions of out-migration. For instance, the Enslaved abroad receive in-migrants from the Export captives and send out-migrants to the Liberated and (via birth) to the Slave-born. The Slave-born, in turn, receive in-migrants as births from the Enslaved abroad and send out-migrants to the Liberated.

Under similar principles, this model could allow for finer distinctions, such as the division of the African population into subpopulations corresponding, for instance, to the western coast, the savanna, and the eastern coast, and could allow for slave raiding of greater or lesser complexity among them. Similarly, the model could distinguish regions in the Atlantic or the Old World.

Discussion of the model for the case of the slave trade to the New World is sufficient, however, to display its basic properties. Thus, although various populations of slaves abroad—for instance, in Jamaica and in Arabia—differed greatly in composition and reproduction, they may each be described in terms of a single set of variables and parameters; it was the differing values of the variables and parameters which made these two populations so different. Let us turn, therefore, to cataloguing the modifications brought to the populations shown in Figure 7.3 through the slave trade.

The most basic parameters in the analysis are the age-specific rates of birth and death for each population. These rates are assumed to be distinct for the free, slave, and captive populations. Further, among free persons, rates of birth and death are assumed to be different in Africa and abroad, and for Source, Captor, and Liberated populations within Africa. Within slave populations, rates are distinct for the Enslaved and the Slave-born. Among Captives, rates are distinct for Domestic, Transit, and Export, and further distinctions could be made within those groups. The remaining parameters consist of age-specific rates of migration: of capture from the Source population,[109] of *partition* among captives to be held in Africa and exported, and of *liberation* of slaves (both the Enslaved and the Slave-born).[110]

The simplest assumption for the parameters is that they remained constant (really, as constant matrices) for any given analysis. Over time, however, it is clear that all the parameters varied. In fact, the life-course and migration parameters might also be treated as functions. Thus the rate of escape was a function of the availability of open land within reach of the slaves; the rate at which captives were exported was a function of the relative prices of slaves in markets in Africa and abroad. In the discussion below, the parameters are labeled as follows (all are age- and sex-specific):

W: annual rate of capture of persons in the Source population
X = 1 - W: annual proportion of Source population avoiding capture
Y: proportion of captives selected for export
Z: annual rate of liberation of slaves
P = 1 - Q: five-year rate of survival
F: annual rate of female births to women

The main relationships involving the parameters may be summarized schematically as follows:

[109] Two possible modifications may be noted here. People already in slavery could be captured and carried off to a new slavery. More broadly, instead of dividing the African population into discrete Source and Captor populations, with only the Source at risk of capture, one could assume that any free African was at risk of capture, or that Source and Captor populations raided each other.

[110] The single schedule of rates of liberation could reasonably be broken down into separate schedules for manumission and escape. The manumission schedule would include high rates for the young and old and for females; the escape schedule would include high rates for adults and for males.

Source × W = Captives
Source × X = Source population remaining after capture
Captives × Y = Transit captives
Captives × (1 - Y) = Domestic captives
Slaves × Z = Liberated
Population × P = Surviving population
Female population × F = Female births

We turn now to the specifics of population projections, first for a closed population and then for migration. Let us consider a free African population which is neither losing population through enslavement nor gaining population through the flight of slaves. A projection of the size and composition of this population over time then follows the standard projection for a closed population. As indicated above, this projection is based on an analysis of five-year age groups from 0-4 to 80+, five-year periods, and a single-sex model of reproduction.

Mortality in each age group above birth is calculated as the age specific survivorship rate multiplied by the previous population. For the Captors:

$$ {}^{C}_{5}N^{t}_{x} = {}^{C}_{5}N^{t-5}_{x-5} \times \frac{{}^{C}_{5}L_{x}}{{}^{C}_{5}L_{x-5}} = {}^{C}_{5}N^{t-5}_{x-5} \times {}^{C}_{5}P_{x-5} $$

For survivors to age 80+, the survival rate is taken as T80/T75.[111] The population in each age group, as estimated for the middle of each five-year period, for Captors, is then

$$ \frac{{}^{C}_{5}N^{t-5}_{x} + {}^{C}_{5}N^{t-5}_{x-5} \times {}^{C}_{5}P_{x-5}}{2} = \frac{{}^{C}_{5}N^{t-5}_{x} + {}^{C}_{5}N^{t}_{x}}{2} $$

Female births in each population are calculated as the age specific annual fertility rate multiplied by the midperiod population, then by five years of exposure, and summed over all childbearing years

$$ {}^{C}B^{f,t} = \sum_{x=\alpha}^{\beta} \left[\frac{({}^{C}_{5}N^{f,t-5}_{x} + {}^{C}_{5}N^{f,t-5}_{x-5} \times {}^{C}_{5}P_{x-5})}{2} \times {}^{C}_{5}F^{f}_{x} \times 5 \right] $$

Survivorship among those born in the current period is calculated as the number of female births multiplied by the female birth survival rate. Male births in each population are calculated as a constant proportion of female births (usually 1.03); survivorship of male babies is determined by the male birth survival rate.

The crude birth rate is then the sum of all male and female births in each five-year period divided by the midpoint population of all age groups totaled. The crude death rate is the sum of

[111] *N* is population by age group (subscript 5 indicates five-year age groups, and *x* indicates ages *x* to *x* + 5; superscript C is the index for Captors, and *t* indicates time *t). L* indicates the number of life-table persons living in each five-year age group ; *P* indicates the probability of survival , in this case from age *x* - 5 to age *x* . *T* indicates the total number of life-table person-years lived in the indicated age group.

all deaths divided by the midpoint population. The crude rate of natural increase is the sum of the birth and death rates.

The next step is to expand the analysis to migration. Migration, of course, increases the complexity of population projection, but a few examples are sufficient to illustrate all of the principles involved in the projection of free and slave populations undergoing enslavement and liberation. These examples are presented in this section. Meanwhile, the smaller captive populations, which logically intervene between those of free and slave, involve still more complexity in projection: they are considered in the following section. In Africa, the Source population remaining after the loss of Captives in each period is as follows:

$$ {}^{S}_{5}N^{t}_{x} = \frac{({}^{S}_{5}N^{t-5}_{x} + {}^{S}_{5}N^{t-5}_{x-5} \times {}^{S}_{5}P_{x-5})}{2} \times X_x \times 5, $$

where *Xx* (or 1 - *Wx)* is the annual age-specific rate of retention by the Source population. This is the midperiod Source population multiplied by the annual rate of retention, over five years of exposure.

The Captor population, in turn, gains liberated slaves in each period, where the liberated slaves come from the Domestic slave population (both Enslaved and Slave-born) , and *Z;* is the annual age-specific rate of liberation to

$$ {}^{C}_{5}N^{t}_{x} = {}^{C}_{5}N^{t-5}_{x-5} \times {}^{C}_{5}P_{x-5} + {}^{C}_{5}M^{t}_{x}, $$

where

$$ {}^{C}_{5}M^{t}_{x} = \left[\frac{{}^{D1}_{5}N^{t-5}_{x} + {}^{D1}_{5}N^{t}_{x}}{2} + \frac{{}^{D2}_{5}N^{t-5}_{x} + {}^{D2}_{5}N^{t}_{x}}{2} \right] \times {}^{D}_{5}Z_x \times 5 $$

The Domestic enslaved population gains in-migrants from surviving Captives and loses out-migrants to liberation:

$$ {}^{D1}_{5}N^{t}_{x} = {}^{D1}_{5}N^{t-5}_{x-5} \times {}^{D1}_{5}P_{x-5} + {}^{DC}_{5}N^{t}_{x} - \frac{({}^{D1}_{5}N^{t-5}_{x} + {}^{D1}_{5}N^{t}_{x})}{2} \times {}^{D}_{5}Z_x \times 5 $$

For the domestic Slave-born population, there is no in-migration (except at birth, as shown below), but there is out-migration because of liberation.[112]

$$ {}^{D2}_{5}N^{t}_{x} = {}^{D2}_{5}N^{t-5}_{x-5} \times {}^{D2}_{5}P_{x-5} - \frac{({}^{D2}_{5}N^{t-5}_{x} + {}^{D2}_{5}N^{t-5}_{x-5})}{2} \times {}^{D}_{5}Z_x $$

Births into this population include births to the Slave-born but also all births to the Enslaved. That is, all children born to Enslaved women are treated as members of the Slave-born populations: they face rates of mortality at birth appropriate to the Enslaved populations, though

[112] This assumes, in effect, that all liberated slaves are manumitted. If it were assumed that some were escapees, one could rewrite the model to include a rate of escape, with the escapees migrating to the Source population.

all deaths (as all survivors) in this group of infants are accounted for with those of the Slave-born populations. For the Slave-born population, female births to Slave-born women are

$$ {}^{D2}B^{f,t} = \sum_{x=\alpha}^{\beta} \left[\frac{({}^{D2}_{5}N_{x}^{f,t-5} + {}^{D2}_{5}N_{x-5}^{f,t-5} \times {}^{D2}_{5}P_{x-5})}{2} \times {}^{D2}_{5}F_{x}^{f} \times 5 \right] $$

Female births to Enslaved women are

$$ {}^{D1}B^{f,t} = \sum_{x=\alpha}^{\beta} \left[\frac{({}^{D1}_{5}N_{x}^{f,t-5} + {}^{D1}_{5}N_{x-5}^{f,t-5} \times {}^{D1}_{5}P_{x-5})}{2} \times {}^{D1}_{5}F_{x}^{f} \times 5 \right] $$

Survivors age 0-4 in the Slave-born population are

$$ {}^{D2}_{5}N_{0}^{f,t} = {}^{D2}B^{f,t} \times {}^{D2}_{5}P_{\text{birth}} + {}^{D1}B^{f,t} \times {}^{D1}_{5}P_{\text{birth}} $$

The projection of captive populations involves the further complication that, during any five-year period, captives experience several different rates of fertility and mortality as they move from freedom to captivity to enslavement. It is assumed that Captives in Africa, be they the Domestic captives retained in Africa or the Transit captives on their way to the coast, suffer one year of exposure to the high mortality rates (and perhaps low fertility rates) of captives in Africa. It is assumed that those who survive to become captives abroad suffer one year of exposure to the high mortality rates (and low fertility rates) of captives crossing the Atlantic, the Sahara, the Red Sea, or the Indian Ocean.

Capture is assumed to take place, on average, in the middle of each five-year period. As a result, in the five-year period of their capture, most captives are exposed to the fertility and mortality rates of the free Source population for the time before their capture, that is, one-half of the period, or 2.5 years. Similarly, those who survive to become slaves within the five-year period are exposed, at the conclusion of their migration, to the fertility and mortality rates of the Enslaved population within Africa, or, alternatively, those of the Enslaved population abroad. The analysis requires, therefore, a decision as to how much exposure each group of captives experienced to the several different rates it faced during the period of capture.

Figure 7.4 displays a schematic summary of the assumed exposure of migrating Domestic captives to various rates of fertility and mortality. Each of five persons is assumed to be captured, successively, in the middle of the first, second, third, fourth, and fifth years of a given period; on average, capture thus occurs at midperiod. Each captive then experiences one year of exposure to Domestic captive rates of fertility and mortality and during the remainder of the period is exposed to Enslaved African rates. The figure includes 25 person-years of experience: the exposures to each set of rates are totalled and divided by 5 to give the portions of a five-year period for each set of rates. Under these conditions, the averages are 2.5 years of exposure to Source rates, 0.9 years of exposure to Domestic captive rates, and 1.6 years of exposure to Enslaved African rates.

One problem remains: A slave captured in the middle of the fifth year experiences one-half year of exposure to Domestic captive rates in this period, and another one-half year of the same exposure in the next period. To account for this systematically, it would be necessary in each period to account for the equivalent exposure for captives left over from the previous

period. This would require a complex system of accounting for a very small population. As a simple and close approximation, therefore, it is assumed that the extra half year of exposure to captive rates takes place in this period rather than in the next, and that a half year of exposure to Enslaved African rates is displaced in exchange from this period to the next. As a result, the average estimated exposure of the five captives is 2.5 years at Source rates, 1.0 years at Domestic captive rates, and 1.5 years at Enslaved African rates.

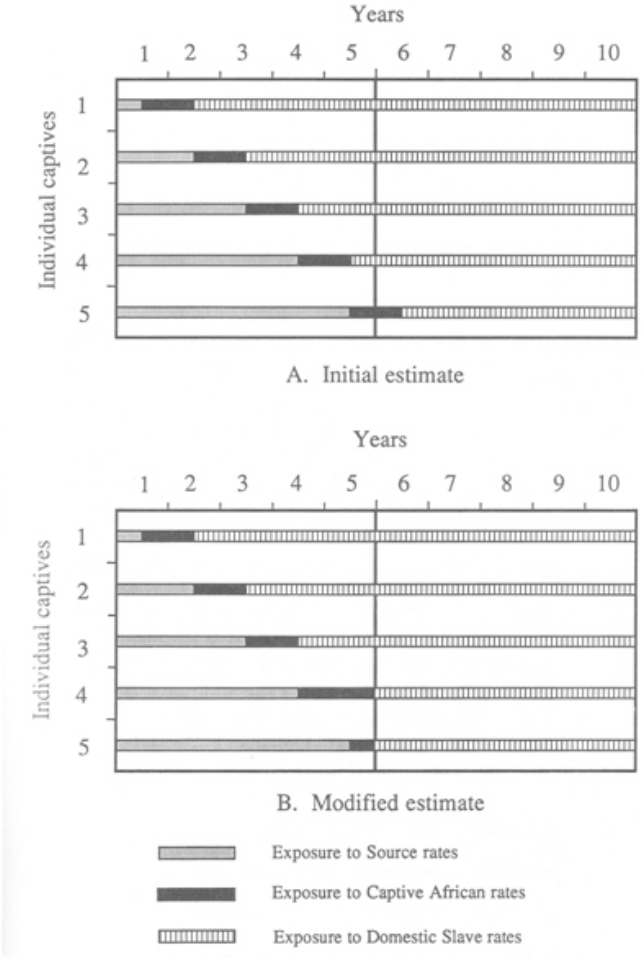

Figure 7.4. Exposure of new Domestic captives

Figure 7.5 displays the equivalent exposure for Transit captives and Captives abroad. As before, capture is assumed to take place at midperiod. Captives then undergo one year's exposure to Transit captive rates, one more year's exposure to Captive abroad rates, and the remainder of the period to Enslaved abroad rates. Average exposures for the captives in a five-year period are 2.5 years' exposure to Source rates, 0.9 years' exposure to Transit captive rates, 0.7 years' exposure to Captive abroad rates, and 0.9 years' exposure to Enslaved abroad rates. Even more complex than before, however, would be the accounting necessary to keep track of the 0.5 years' Transit captive exposure and the 1.5 years' Captive abroad exposure in the following period. By the same logic as above, therefore, Enslaved abroad exposure in this period is exchanged for captive exposure in the next period, and the results remain a close approximation of the more accurate

but more complex formulation. In sum, the allocation of the 5.0 years' exposure of these captives is 2.5 years at Source rates, 1.0 years at Transit captive rates, 1.0 years at Captive abroad rates, and 0.5 years at Enslaved abroad rates. (These varying periods of exposure must be kept in mind when one calculates, as we do below, the number of person-years lived in each period for calculations of crude rates of birth, death, and growth.)

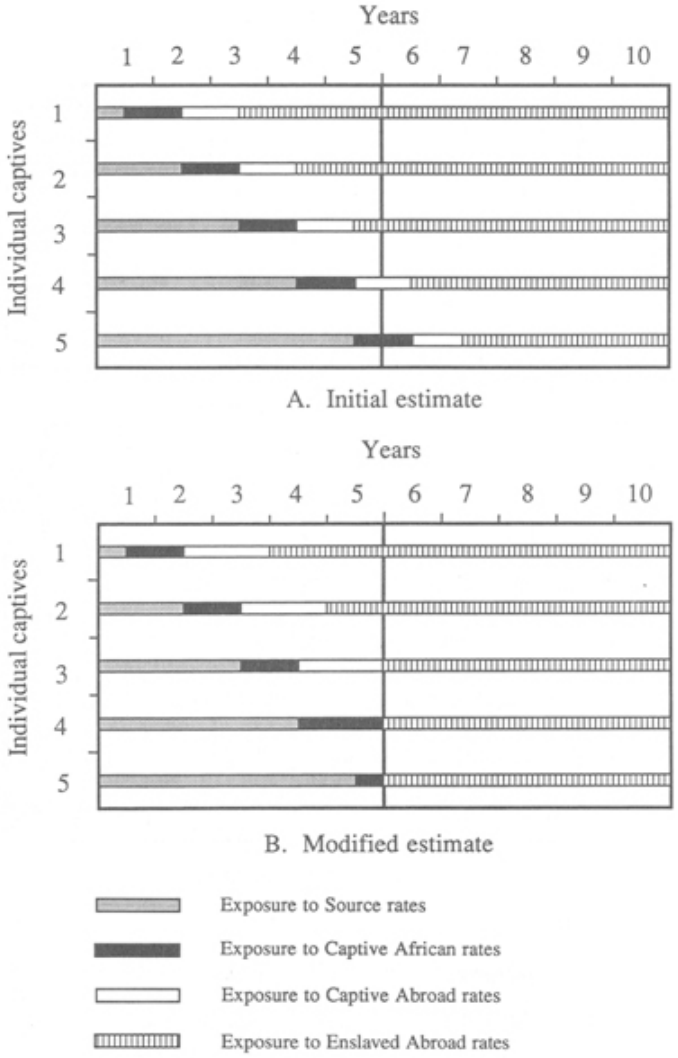

Figure 7.5. Exposure of new Export captives

These rates of exposure may now be used in calculating the fertility and mortality of migrating captives. For Domestic captives , the number of captives for each age and sex is the midperiod Source population multiplied by the annual enslavement rate (X) and by the complement of the partition rate (l - Y), which gives the number of captives intended for slavery in Africa:

$$ {}^{DC}_{5}N^{t}_{x} = \frac{({}^{S}_{5}N^{t-5}_{x} + {}^{S}_{5}N^{t-5}_{x-5} \times {}^{S}_{5}P_{x-5})}{2} \times {}_{5}X_{x} \times 5 \times (1 - {}_{5}Y_{x}) $$

Survivorship for Domestic captives is the product of three rates of survival over a period of 5.0 years: those of the Source population (2.5 years), of Domestic captives (1.0 year), and of Enslaved Africans (1.5 years):

$$ {}^{DC}_{5}N^{t}_{x} = {}^{DC}_{5}N^{t-5}_{x-5} \times {}^{S}_{2.5}P_{x-5} \times {}^{DC}_{1}P_{x-5} \times {}^{D1}_{1.5}P_{x-5} $$

Fertility among Domestic captives is the sum of three rates of fertility, multiplied by the midperiod female population for each childbearing age group:

$$ {}^{DC}B^{f,t} = \sum_{x=\alpha}^{\beta} \left[\frac{({}^{DC}_{5}N^{f,t-5}_{x} + {}^{DC}_{5}N^{f,t}_{x})}{2} \times (2.5 \times {}^{S}_{5}F^{f}_{x} + 1.0 \times {}^{DC}_{5}F^{f}_{x} + 1.5 \times {}^{D1}_{5}F^{f}_{x}) \right] $$

Survivors among the newborn female Domestic captives are calculated as female births multiplied by the product of the three birth survival rates, at the relevant exposure. Male births, as elsewhere, are 1.03 times female births, and survivorship is determined by male birth survival rates.

Surviving Domestic captives enter the Enslaved population in Africa as in-migrants. That is,

$$ {}^{D1}_{5}N^{t}_{x} = {}^{D1}_{5}N^{t-5}_{x-5} \times {}^{D1}_{5}P_{x-5} + {}^{D1}_{5}M^{t}_{x}, $$

where

$$ {}^{D1}_{5}M^{t}_{x} = {}^{DC}_{5}N^{t}_{x}. $$

The captives sent abroad first enter the Transit population, then the Export captive population, and the survivors join the Enslaved population abroad. The initial Transit population in each period is the complement of the initial Domestic captive population:

$$ {}^{CE}_{5}N^{t}_{x} = \frac{({}^{S}_{5}N^{t-5}_{x} + {}^{S}_{5}N^{t-5}_{x-5} \times {}^{S}_{5}P_{x-5})}{2} \times {}_{5}X_{x} \times 5 \times {}_{5}Y_{x} $$

Survivorship for the Transit population is calculated as the product of two survival rates over the 3.5 years of each five-year period which the average exported captive spends in Africa:

$$ {}^{CE}_{5}N^{t}_{x} = {}^{CE}_{5}N^{t-5}_{x-5} \times {}^{S}_{2.5}P_{x-5} \times {}^{DC}_{1}P_{x-5} $$

Fertility among Transit captives is the sum of two rates of fertility:

$$ {}^{CE}B^{f,t} = \sum_{x=\alpha}^{\beta} \left[\frac{({}^{CE}_{5}N_x^{f,t-5} + {}^{CE}_{5}N_x^{t})}{2} \times (2.5 \times {}^{S}_{5}F_x^{f} + 1.0 \times {}^{DC}_{5}F_x^{f}) \right] $$

Survivors among the Transit captives leave sub-Saharan Africa as Export captives.

For Export captives, finally, mortality is calculated over the 1.5 years of each five-year period which the average export captive spends abroad.[113]

$$ {}^{CE}_{5}N_x^{t} = {}^{CE}_{5}N_x^{t-1.5} \times {}^{CE}_{1}P_x \times {}^{E1}_{0.5}P_x $$

Fertility among Export captives is:

$$ {}^{CE}B^{f,t} = \sum_{x=\alpha}^{\beta} \left[\frac{({}^{CE}_{x}N_x^{f,t-1.5} + {}^{CE}_{5}N_x^{f,t})}{2} \times (1.0 \times {}^{CE}_{5}F_x^{f} + 0.5 \times {}^{E1}_{5}F_x^{f}) \right] $$

Survivors among the Export captives enter the Enslaved population abroad as in-migrants at the end of the current period.
That is,

$$ {}^{E1}_{5}N_x^{t} = {}^{E1}_{5}N_{x-5}^{t-5} \times {}^{E1}_{5}P_{x-5} + {}^{E1}_{5}M_x^{t}, $$

where

E15Mtx= CE5Ntx

Of the many elaborations which could be made to this model, let us mention those which seem most relevant to issues which have been discussed in the slave trade literature, Captives headed for service in Africa could be divided into those marching and those undergoing seasoning. Transit captives could be divided into those marching and those living in barracoons. Captives abroad could be divided into those on ships and those undergoing seasoning.

Where Captives are defined here as people captured within the current five-year period, the Liberated population includes any person liberated during this *or a previous* five-year period. As noted above, it is assumed that the migration from slavery to freedom is instantaneous and uneventful, while the migration from freedom to slavery is fraught with peril. The Liberated population in Africa, for instance, is calculated as the forward projection of the previous

[113] Note the change of indices from previous calculations: the full exposure to mortality comes, on average , within the last half of the period.

Liberated population plus the number of liberated immigrants from both the Enslaved and the slave-born populations.[114]

Calculating Crude Demographic Rates from composition-specific rates. For each population, we may use the information from the above population projections to calculate crude rates of birth, death, migration, growth, and decline. The crude rate of migration for any population, for instance, depends on the age-specific rates of birth, death, and migration and on the age and sex composition of that population. (The age-specific rates of birth, death, and migration are taken as data, or sometimes by assumption, in the model.) All of these crude rates can be calculated in straightforward fashion from the population projections outlined above.

Thus, the crude birthrate in Africa during any period is calculated as the total of births among Free, Slaves, and Captives divided by the mid-period population total for Free, Slaves, and Captives (excepting Captives who have been sent abroad). The crude birthrate among Africans abroad is calculated as the total of births among Free, Slaves, and Captives abroad divided by the mid-period population total for Free, Slaves, and Captives abroad. Death rates are calculated similarly.[115]

Some additional, useful variables may be calculated for study of the slave trade and expressed in terms of crude rates. One of these is *excess deaths:* deaths occurring because of the slave trade over and above those which would have occurred in the African Source population. Four distinct rates of African population loss provide a useful composite picture of the demographic toll of the slave trade. The *crude rate of out-migration* from Africa is calculated as the mid-period Transit population divided by the mid-period total for Free, Slave, Domestic captive, and Transit populations. The *crude growth rate* of African population is calculated as the number of births less the number of deaths among the Free, Slaves, and Captives in Africa, less the number of out-migrants (Captives abroad), divided by the mid-period total for the Free, Slave, Domestic captive, and Transit populations. The *crude rate of decrement* in African population leaves out the births; it is calculated as the number of deaths among Free, Slaves, and Captives in Africa plus the number of out-migrants (Captives abroad), divided by the mid-period total for Free, Slave, Domestic captive, and Transit populations. The *crude rate of enslavement* decrement in African population is calculated as the number of excess deaths among Captives in Africa plus the number of out-migrants, divided by the mid-period African population total.

In addition, the model allows for the aggregation of migrants into *cumulative totals*. The best-known example of a cumulative total is Curtin's estimate of 9.6 million slaves landed in the New World between 1500 and 1850. This type of figure, while often quoted in migration studies, has an analytical weakness in that, because it has no dimension of time, it cannot be

[114] Here it is assumed that the rate of liberation, Z,; is the same for both Enslaved and Slave-born populations. This assumption could, of course, be relaxed.

[115] For Captive populations, crude rates could be calculated in two ways. The first would include only the births or deaths during the period of capture, transit, and seasoning (one or two years in a five-year period), as a proportion of person-years lived during the one or two years in question . The second would include the births or deaths during a five-year period including capture, as a proportion of person-years lived during the five years. Death rates calculated in the first way would be higher than those calculated in the second way.

compared to a population at risk. Nonetheless, a substantial body of historical research and debate is built on cumulative totals of African slave migrants (Curtin 1969, Thomas 1968). The model allows for the estimation of cumulative totals not only for captives arriving in the New World but for the number of captives, enslaved, liberated, and even excess deaths, and for the Orient and within Africa.

Practical implementation of the formal model requires that one link it to historical data on slave populations. While data are very scarce for many of the variables specified in the model, the process of migration links the variables sufficiently closely that limited historical data may provide important insights into broad patterns of slave demography. Information on the age and sex composition of slaves making the middle passage (Export captives, in the terminology used here) yields powerful inferences about the age and sex composition of the population remaining in Africa. Estimated growth rates of New World slave and free black populations, respectively, suggest limits for the estimation of equivalent rates in Africa. On the other hand, for certain crucial variables, the absence of sound historical data greatly weakens the analytical and predictive power of the model. We face a serious shortage of data on overall rates of capture and on the age and sex breakdown of captives; on the rates of partition among domestic and export slaves; and on the rates of mortality for captives within Africa.

The Composition-specific Model in Matrix Terms

In this section, we concisely restate the dynamics of the composition-specific model presented in the previous section using matrices and matrix multiplication. Consider four sub-populations of interest: Source, Captors, Domestic slaves, and Export slaves. We can use a vector to represent the size of each population, by gender, at time t:

$$N(t) = \begin{vmatrix} N_{SF}(t) \\ N_{SM}(t) \\ N_{CF}(t) \\ N_{CM}(t) \\ N_{DF}(t) \\ N_{DM}(t) \\ N_{EF}(t) \\ N_{EM}(t) \end{vmatrix},$$

where the first subscript refers to sub-population, and the second refers to gender. Note that N is actually a vector of vectors. For example, N_{SF} is a vector containing 17 elements, each corresponding to the size of one of the 17 age groups in the female Source population.

Our goal is to find a matrix U such that $N(t+5) = UN(t)$. As the matrix U will have a certain structure, it will be convenient to utilize block matrix notation. In doing so, we can write our large matrix U as an array of smaller matrices. In our case, we can write

$$I = \begin{bmatrix} 1 & & \\ & \ddots & \\ & & 1 \end{bmatrix}_{34\times 34} \quad ; \quad C = \begin{bmatrix} c_{1,f} & & \\ & \ddots & \\ & & c_{17,m} \end{bmatrix}_{34\times 34}$$

The first subscript represents the sub-population an individual belongs to at time t. The second subscript represents the sub-population that same individual will belong to at time $(t+5)$. We will adopt the convention of referring to a given "block" of matrices as $U_{\text{from to}}$. For example, we shall refer to the block

$$\begin{array}{c|c} U_{SF,SF} & U_{SM,SF} \\ \hline U_{SF,SM} & U_{SM,SM} \end{array}$$

simply as U_{SS}.

Since many of the smaller matrices will contain only zeroes, we may therefore reduce U to

$$U = \left[\begin{array}{c|c|c|c} \begin{array}{c|c} U_{SF,SF} & \\ \hline U_{SF,SM} & U_{SM,SM} \end{array} & & & \\ \hline & \begin{array}{c|c} U_{CF,CF} & \\ \hline U_{CF,CM} & U_{CM,CM} \end{array} & & \\ \hline \begin{array}{c|c} U_{SF,DF} & U_{SM,DF} \\ \hline U_{SF,DM} & U_{SM,DM} \end{array} & & \begin{array}{c|c} U_{DF,DF} & \\ \hline U_{DF,DM} & U_{DM,DM} \end{array} & \\ \hline \begin{array}{c|c} U_{SF,EF} & U_{SM,EF} \\ \hline U_{SF,EM} & U_{SM,EM} \end{array} & & & \begin{array}{c|c} U_{EF,EF} & \\ \hline U_{EF,EM} & U_{EM,EM} \end{array} \end{array}\right].$$

Each block of matrices along the diagonal corresponds to individuals remaining in their given sub- population. For example, U_{SS} governs the evolution of the source population. In particular, $U_{SF,SF}$ describes how the time t female source population relates to the time $t+5$ female source population, and $U_{SM,SM}$ describes how the time t male source population relates to the time $t+5$ male source population. The number of male births in a 5-year period is a function of the size of the female population at time t, and is determined by $U_{SF,SM}$. To be clear, the 0 in the upper right position stems from the fact that the number of females at time $t+5$ in no way depends on the number of males at time t. Other blocks along the diagonal have an analagous meaning for the corresponding sub-population.

The off-diagonal blocks describe the nature of migration from one sub-population to another. For example, when taking the product $UN(t)$, the large zeroes in the last three

columns of the first row of U, align with the rows of $N(t)$ corresponding to the Captor, Domestic slave, and Export slave populations. This is tantamount to the fact that no individual from any of these three sub-populations will become part of the source population.

Meanwhile, when taking the product $UN(t)$, USD and USE each align with the rows of $N(t)$ corresponding to the Source population. This represents individuals being taken from the Source population and placed into the Domestic slave and Export slave populations, respectively.

We now consider the various structures of the small matrices that make up U. Many similarities exist across blocks. For example, UCC, UDD, and UEE vary from one another only with respect to different survival and fertility rates amongst the respective sub-populations. USS varies from UCC, UDD, and UEE only with respect to different survival and fertility rates, as well as capture rates. Similarly, USD and USE vary from one another only with respect to survival, fertility, and partition rates.

Let us first focus on the USS. We are working under the assumption that events happen in the order:

1. Migration (capture)
2. Death and/or aging
3. Birth (assumed to occur mid-period)

We can express the relevant portion of the population vector as

$$N_S(t) = \begin{vmatrix} N_{S_{f,1}}(t) \\ \vdots \\ N_{S_{f,17}}(t) \\ N_{S_{m,1}}(t) \\ \vdots \\ N_{S_{m,17}}(t) \end{vmatrix}.$$

We wish to construct USS so that $NS(t+5) = USSNS(t)$. To facilitate the first event, migration, let us introduce two additional matrices, $\boldsymbol{I}$ and C:

$$I = \begin{bmatrix} 1 & & \\ & \ddots & \\ & & 1 \end{bmatrix}_{34\times 34}; \qquad C = \begin{bmatrix} c_{1,f} & & \\ & \ddots & \\ & & c_{17,m} \end{bmatrix}_{34\times 34}$$

The subscripts on the matrices indicate that each has 34 rows and 34 columns (17 age groups $\times$ 2 genders). The elements of C represent the various proportions of each age group and gender who are captured each period. For example, $c_{1,f}$ is the proportion of the 0-5 age group of females

who are captured. Correspondingly, the elements of the matrix $(I - C)$ represent the various proportions of each age group and gender who avoid capture in a given period.

Also let us introduce the matrix SS, whose elements represent the proportions of each age group and gender within the Source population who survive from the beginning of one 5-year period to the next. Then

$$SS = \begin{bmatrix} 0 & 0 & 0 & 0 \\ s_{1,f} & 0 & 0 & 0 \\ 0 & \ddots & \ddots & 0 \\ 0 & 0 & s_{16,m} & 0 \end{bmatrix}_{34\times 34}.$$

All of the survival proportions show up one diagonal beneath the main diagonal, and all other elements are zero. The effect of on a population vector when multiplied by SS, is that each group undergoes mortality, and is then relocated to the subsequent age group. For example, the fact that the first row of SS is all zeroes has the interpretation that the 0-5 age group for females is "zeroed out", and will only gain new entrants via female births (see below). The fact that the second row of SS contains the entry $s1,f$ followed by all zeroes has the interpretation that a female in the 0-5 age group gains entry into the 5-10 age group if and only if she survives five years of exposure to the mortality rate $s1,f$.[116]

Finally let us introduce the matrix, FS, whose elements represent the birth rates of each age group and ge

$$FS = \begin{bmatrix} b_{1,f} & \dots & b_{17,f} & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & 0 & \dots & 0 \\ 1.03 \times b_{1,f} & \dots & 1.03 \times b_{17,f} & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & 0 & \dots & 0 \end{bmatrix}_{34\times 34}.$$

Only two rows have non-zero entries. The 1st and 18th rows yield the number of females and males, respectively, that will enter the 0-5 age group. The notation bi,f is the average annual number of female newborns who survive to a female in age group i.[117] Therefore the total number of new female births each time period is given, as above, by

$$\begin{bmatrix} b_{1,f} & b_{2,f} & \dots & b_{17,f} \end{bmatrix} \times N_{SF}(t) = \begin{bmatrix} b_{1,f} & b_{2,f} & \dots & b_{17,f} \end{bmatrix} \times \begin{bmatrix} N_{SF_1}(t) \\ \vdots \\ N_{SF_{17}}(t) \end{bmatrix}.$$

[116] We are using 16 survival rates for 17 age groups. This essentially forces the oldest group to completely die off each period, but we compensate for this simply by increasing slightly $s16,f$ and $s16,m$.

[117] In fact, many of the bi,f's are also zero, as we take for a female's child-bearing years ages 15-49.

The number of male births is taken as 1.03 × female births, which results in approximately 50.7% of new births being male.

We are now equipped to state the overall form of USS. Recall that, by convention, new births are calculated using mid-period sub-populations. That is, the fertility rates are applied to the average of the initial sub-population and the sub-population remaining after exposure to 5 years of capture and mortality. These characteristics of our model can be concisely summarized as[118]

$$\begin{aligned} N_S(t+5) &= F_S \times \frac{1}{2}(S_S(I-M)+I)N_S(t) + S_S(I-M)N_S(t) \\ &= \underbrace{\left[F_S \times \frac{1}{2}(S_S(I-M)+I) + S_S(I-M)\right]}_{U_{SS}} N_S(t). \end{aligned}$$

With the previous discussion behind us, deriving the rest of the matrices that make up U is straightforward. As mentioned above, UCC, UDD, and UEE have structures very similar to that of USS, the biggest exception being that no one is removed from the sub-populations via capture. In fact, utilizing a similar brand of notation as above, the Captor sub-population at time $t+5$ can be written as

$$N_C(t+5) = F_C \times \frac{1}{2}(S_C + I)N_C(t) = U_{CC}N_C(t).$$

Similarly, the Domestic and Export slave populations at time $t+5$ evolving from individuals already enslaved at time t are

$$F_D \times \frac{1}{2}(S_D + I)N_D(t) = U_{DD}N_D(t), \quad \text{and}$$
$$F_E \times \frac{1}{2}(S_E + I)N_E(t) = U_{EE}N_E(t).$$

The matrices USD and USE describe how individuals move from the Source population to the Domestic and Export slave populations, respectively. To obtain their structure, let us introduce one last matrix, P, the elements of which govern what proportion of captured individuals are retained as Domestic slaves, and what proportion are sent abroad as Exports:

$$P = \begin{bmatrix} p_{1,f} & & \\ & \ddots & \\ & & p_{17,m} \end{bmatrix}_{34\times 34}.$$

[118] Note that this expression illuminates the fact that if we know the composition of the Source population at time t and we can find the inverse of USS, then we can determine the composition of that Source population at time $t-5$:

$$U_{SS}^{-1} N_S(t) = U_{SS}^{-1} U_{SS} N_S(t-5) = I N_S(t-5) = N_S(t-5).$$

Unfortunately, however, USS is not quite invertible. We shall return to this matter in Chapter 8.

Each of the p's indicate the proportion of the given age and gender group that is retained as Domestic slaves. Therefore, elements on the diagonal of the matrix $I - P$ represent the proportion of each age and gender group sent abroad. Therefore the number of new arrivals to the Domestic and Export slave groups are

$$F_D \times \frac{1}{2}(S_D PMN_S(t)) + S_D PMN_S(t) = F_D \times \frac{1}{2}(S_D PM + S_D PM)N_S(t)$$
$$= \underbrace{F_D S_D PM}_{U_{SD}} N_S(t)$$

and

$$F_E \times \frac{1}{2}(S_E(1-P)MN_S(t)) + S_E(1-P)MN_S(t) = F_E \times \frac{1}{2}(S_E(1-P)M + S_E(1-P)M)N_S(t)$$
$$= \underbrace{F_E S_E(1-P)M}_{U_{SE}} N_S(t),$$

respectively, which enables us to calculate $N_D(t+5)$ and $N_E(t+5)$ as

$$N_D(t+5) = F_D \times \frac{1}{2}(S_D + I)N_D(t) + F_D S_D PMN_S(t) \quad \text{and}$$
$$N_E(t+5) = F_E \times \frac{1}{2}(S_E + I)N_E(t) + F_E S_E(1-P)MN_S(t).$$

Migration Data: "Multiple Perspectives" and "Voyage-based" Approaches

All of the above discussion on population and migration assumes that we have complete data on the various populations. But data are incomplete. Here we discuss overlapping categories of migration data: cases with no available documentation, cases with qualitative documentation, and cases with voyage-based data (distinguishing those cases with complete data from cases with incomplete and missing data).

Philip D. Curtin launched a major research effort with his 1969 book, *The Atlantic Slave Trade: A Census.* In this work, relying on a mixture of primary and secondary research, Curtin collated data drawn from a wide range of authors, methods, and sources, to propose that the total number of persons embarked on ships for transatlantic slave trade, from 1450 to 1867, equaled roughly 9.6 million individuals. While some of his data consisted of enumerations of captives along certain routes, much of his analysis consisted of indirect estimations. The result established a figure of an order of magnitude that has been shown to be robust, although there have been many modifications to his estimates and an overall inching upward of his proposed total, as new documentation has been located and analyzed.

Curtin's "multi-perspectival approach" to estimating the migration of African captives has dominated most areas of research, relying on wide-ranging research gathering and eclectically analyzing data relevant to the volume of the trade. For the Atlantic slave trade, the

response to Curtin's work, as noted in earlier chapters of this volume, led to an extraordinary expansion in research on the Atlantic slave trade. Much of it consisted of archival research revealing individual voyages and the size of their slave cargoes; but the research also consisted of indirect estimates based, for instance, on the size and growth rate of New World slave populations. Altogether, it may be said that this phase of the research on Atlantic slave trade focused on a "multiple perspectival approach," For the slave trade to the North and East of sub-Saharan Africa, Ralph A. Austen composed a systematic set of estimates of Saharan, Red Sea, Ethiopian, and Swahili coast slave exports, and other scholars filled in further details. Multiple-perspective analysis remains the best standard for situations without systematic voyage-based data: trans-Saharan, Red Sea, Indian Ocean trade. Similarly, multi-perspectival approaches are applied in studies of slave trade to Europe and Atlantic islands, and to study of further migrations of captives in the Americas and in other regions. Finally, and of great importance, enslavement and slave trade on the African continent can best be analyzed through the eclectic, multiple-perspective approach.

Voyage-based approaches have become dominant for the Atlantic slave trade, and have developed to some degree in other trades. From the 1970s, Jean Mettas pioneered the approach of systematically documenting individual slaving voyages implemented it in two nearly definitive volumes on the French slave trade.(Mettas 1978, 1984) In the early 1990s, David Eltis led in generalizing this approach to the Atlantic slave trade generally, working with David Richardson, Herbert S. Klein, and Stephen Behrend. Eltis and his colleagues emphasized the term "voyage-based approach," building a dataset organized around the documentation of the many thousands of transatlantic slaving voyages, each with a discrete point of origin and points of trade up to the conclusion of the voyage. The first edition of this work, published as the Dubois Institute Database, included data on some 27,000 voyages; a second edition of the work, *Slave* Voyages, published in 2008 and updated in 2010, included data on over 34,000 voyages.

One important contrast between the multiple-perspectives and voyage-based approaches is that, for a given space and time, the former relied on making direct estimates of numbers of captives while the latter focused on documenting voyages, and only then on estimating numbers of captives. In particular, while some reports on voyages gave precise numbers of captives transported, many other voyages left few details or none at all on numbers of captives. The point is that data on slave voyages had *missing data* for a substantial number of captives – usually a majority. Chapter 9 discusses two principal methods for estimating the missing data.

An additional point about the voyage-based approach to migration data is that, while it is relatively specific in the data it includes, it also excludes certain types of migration data. That is, the transatlantic slave trade databases do not include data or approximations on enslavement on the African mainland; on slave trade to Atlantic islands, Europe, and Asia; nor on subsequent movements of captives within the Americas.(O'Malley 2014)

Conclusion: Comprehensive statement of the model

Our general model allows for a comprehensive, systematic survey of African population and migration. The variables included and excluded are noted explicitly, leaving readers the opportunity to reformulate the model. This comprehensive approach, while it does not eliminate

the possibility of error, does address and resolve many of the errors of omission in previous analyses. Through its inclusion of the whole African continent, destinations in the African diaspora, and the whole period from 1650 to 2000, it calls attention to consistency and variation in analysis of population change.

In sum, the analysis relies on basic principles of crude-rate and composition-specific models of population change, applying combinations and variants of these models to times and spaces within the overall scope of study (Africa, 1650-1960), according to the nature and quantity of data available and the statistical techniques appropriate for such data.

The general model of population change, when implemented through its variants, yields a range of estimates of population. In some cases we are able to apply multiple variants of the model to a given historical situation. For instance, for the era from 1790 to 1890, we calculate three different variants of the rate of enslavement of people within Africa, so that we get three sets of estimates of population for each region, each of them surrounded by a margin of error. That is, the range of estimates includes not only the error margin of 95% confidence on either side of the modeled estimate, but also the principal estimate and the error margin for adjoining variants of the model. The selection of a preferred set of estimates of population of migration—and the identification of the error margin surrounding the preferred estimates—is a matter of judgment which to which we return in Chapter 11.

Chapter 8

Characteristics of the Models

Crude-rate Strategy for Estimating Populations
Colonial Era: Analytical Procedure
Colonial Era Input Data
Crude-rate analysis for precolonial times
Composition-specific analysis: Estimating the sensitivity and range of variation
Composition-specific Strategy for projecting populations, 1650 to 1790
Error margins
Conclusion

This chapter introduces the specific datasets used in population calculations and presents statistical analysis of the sensitivity, interactions, and error margins of results calculated through the model. The chapter also presents additional details on calculations of decennial populations.

Crude-rate Strategy for Estimating Populations

Colonial Era: Analytical Procedure. The overall strategy of the population estimates is to set a framework for analysis and projection of populations, make an initial set of projections, then revise and update them. I identify a base population for each national or sub-national territory in the years 1950 and 1960 and then project backward at high and low rates. In projecting populations back to 1890, we attempt to estimate variations in growth rates for each territory and each decade, relying on available demographic data and hypothesized changes in epidemiology, overseas slave trade, continental slave trade, and other social and political conditions. The details of the territories analyzed, base populations, and decennial growth rates—and their interactions with each other—are described in what follows at two levels of detail. First, the eight bulleted points in this section describe, in telegraphic form, the full analysis for the colonial era. Then the remainder of this section describes the same analysis in more discursive, detailed fashion.

- **Step 1—Define Territories**.
- **Step 2—Identify Base-year Populations for 1950 and 1960**. From United Nations estimates as modified by other data, project base populations by nation for 1950 and 1960. Document or interpolate for sub-colony regions, and project their populations for 1950 and 1960. Estimates are summarized in Appendices B1 and B2.

- **Step 3—Explore Data and Assumptions on Growth Rates, 1890-1950**. For colonies and sub-colonies as defined in Step 1, collect available demographic data and consider the range of possible annual growth rates for decennial periods, 1890-1950, based on empirical, comparative, and speculative approaches. This step includes comparison to contemporaneous growth rates in regions of India.
- **Step 4—Set Base-level Growth Rates, 1890-1950**. Select continent-wide base-level (that is, estimated median continental) growth rates per decade, reflecting average or expected growth rates, 1850-1950. Estimate the decennial African populations associated with these growth rates. Estimates displayed in Table 8.2.
- **Step 5—Explore Regional Variations in Growth Rates**. Based on review of empirical data (from Step 3), propose estimates of positive or negative adjustments to base-level growth rates caused by such situations as slave trade within Subsaharan Africa, export slave trade, disorder from slave trade, post-slave-trade recovery, migration of free people to or from adjoining colonies, population decline through colonial oppression, benefits of income growth, or varying local health conditions. Summaries of regional variations in growth rates in Table 8.3.
- **Step 6—Estimate Growth Rates Revised for Local Conditions and Slave Exports**. Working back from 1950 to 1890 for each region, modify growth rates based on varying local conditions including slave trade (Step 5).
- **Step 7—Low, Mid, and High Population Projections, 1890-1950**. To the revised growth rates from Step 6, add tolerances of plus and minus 0.1% (or one per thousand) to each earlier decennial growth rate for each territory, so that there will be a high and low growth rate at each stage. Calculate low, mid, and high population estimates for each region in each decade, and aggregate them as appropriate.
- **Step 8—Review of Error Margins.** Discussion of sources of error in data and methodology, techniques for verifying or rejecting the hypothesized population estimates, and alternative methods of analysis. This can include sensitivity analysis of the interactions among variables in the crude-rate calculations.

Colonial Era Input Data. We begin by identifying base-year populations for 1950 and 1960. From United Nations estimates as modified by other data, we can project base populations by nation for 1950 and 1960. We can document or interpolate for sub-colony regions, and project their populations for 1950 and 1960. Estimates are summarized in Table 8-1. We have chosen to identify base populations for 1950 and 1960, thus including the growth rate linking them, on the argument that this provides the most robust statement of each base population. We have based our estimates first on U.N. estimates of 2006.[119] (For Ghana and Nigeria, where analyses of the 1950s were exceptionally strong, one may still ask whether the current UN estimates are improvements over the initial figures.[120]) While both 1950 and 1960

[119] United Nations, *World Population Prospects*. We have relied upon the 2006 estimates of territorial population for 1950 and 1960. The Tabutin-Shoumaker survey of sub-Saharan Africa relied on the 2002 estimates, and the same authors in surveying North Africa and the Middle East relied on the 2004 estimates. We have accepted the argument that the 2006 estimates, which differ in various details from the earlier series, are to be preferred. We are thankful to Sabine Henning of the United Nations Population Division for generously providing a set of total African national populations for 1950 and 1960 as estimated in 2002, 2004, and 2006.

[120] We refer to the Okonjo estimate of 1962 population of Nigeria, and on the Ghana census of 1960.(Okonjo, "Population of Nigeria"; Gill, *Population of Ghana*) Other countries for which discrepancies arose between 1967

are treated as base years, in practice the 1950 population estimate for each territory is used as the basis for projection of earlier populations.

Table 8.1. African Population in the National Era: United Nations Estimates.
Source: United Nations Population Division, "World Population Prospects: The 2006 Revision."

	Population 1950	Population 2000	Average Annual Growth Rate 1950-2000 (%)
Africa	220,263,472	817,673,000	2.66%
Sub-Saharan Africa	176,150,472	676,586,000	2.73%
West & Central Africa	90,027,000	336,684,000	2.67%
East & Northeast Africa	70,446,595	275,296,000	2.76%

After evaluation of the data and alternative assumptions summarized in Step 3, we have chosen to project preliminary or "base-level" decennial growth rates for Africa as a whole, ranging from a low of 2 per thousand for the 1850s to a high of 15 per thousand for the 1940s. These are estimates of average or expected crude growth rates, not accounting for export slave trade. Our overall assumption is that death rates declined at an accelerating rate from the mid-nineteenth to the mid- twentieth century, while birth rates remained relatively constant, so that net rates of population growth increased over time throughout the continent.[121] For the 1910s and 1930s, we assumed slight declines in growth rates from preceding decades because of war, economic depression, and fertility decline, in parallel with apparent declines in India. We assumed growth rates of no more than 0.2% in the mid-nineteenth century because the high insecurity of that era.

Figure 8.1 and Table 8.2 show these base-level growth rates, and also shows the tolerance that would result from adding and subtracting a growth rate of 0.1% cumulatively, each decade.[122] This projection shows low and high populations of 131 and 169 million, respectively, for 1850 as compared with 284 million for 1960. The resulting medium estimates for African population—149 million in 1850 and 155 million in 1900—are significantly higher than the received estimates of Willcox, Carr-Saunders, Biraben, and others.(Biraben 2003, McEvedy and Jones 1978, Durand 1967, Willcox 1931, Carr-Saunders 1964, pp. 34-35) The assumption of relatively low growth rates for the nineteenth century leads logically to these higher estimates of African population size in the nineteenth century and, indeed, in earlier times.

UNECA figures and later U.N. figures are Guine-Bissau, Central African Republic, Gabon, Congo-Brazzaville, and Mozambique: in these cases we relied on the later U.N. figures. Growth rates in the 1950s appear generally to have been higher in East Africa and North Africa than in West Africa. Thanks to J. C. Caldwell for advice on these points.

[121] [Ittman VII: need footnote or comment explaining why I make the assumption.]

[122] The tolerances are cumulated: that is, the tolerance is ± 1% for 1941, 2% for 1931, and 10% for 1851.

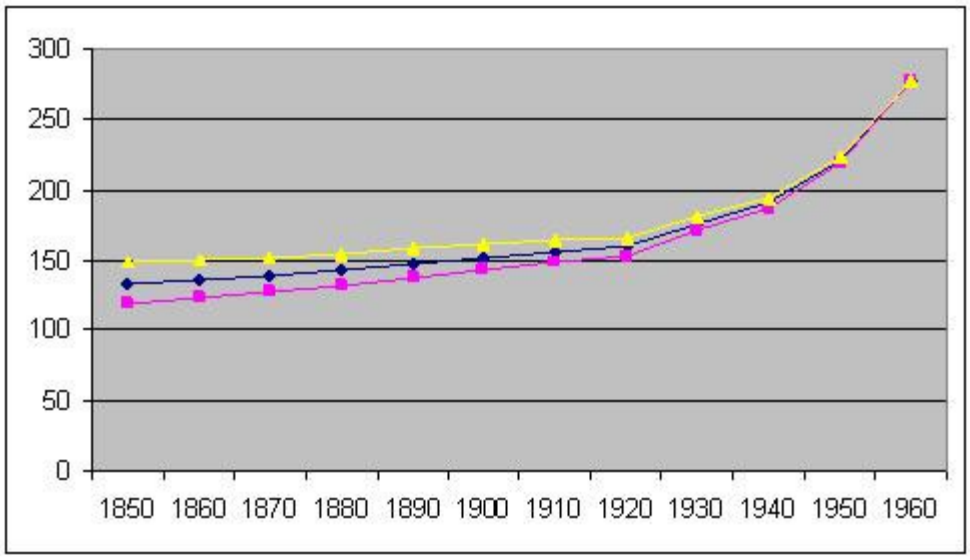

Figure 8.1: Base-level Growth Rates, Showing Tolerances. TO 1890

Decade	Annual %-age Growth Rate
1951-60	2.3
1941-50	1.5
1931-40	0.8
1921-30	1.0
1911-20	0.2
1901-10	0.3
1891-00	0.3

Table 8.2: Africa - Base-level Growth Rates TO 1890

We turn now to the issue of regional variations in growth rates according to any specific circumstances that can be identified. Before attempting detailed analysis of the available data, we propose a list of social circumstances for which one can project increases or decreases in population growth rates. Table 8.3 lists the eight situations we propose, along with estimates of the magnitude of the annual effect of each situation on population growth.

Table 8.3. Situational Modification to Growth Rate

Type of Modification	**Maximum Annual Magnitude** Percent
a. Slave-trade disorder	-0.2
b. Sub-Saharan slave exchanges	+ or -0.3
c. Sub-Saharan slave exports	-0.6
d. Post-slave-trade recovery	+0.4
e. Colonial disorder	-0.4
f. Income growth	+0.2

g. Migration of free people	+ or -0.6
h. Epidemic and famine	-0.5

The first three categories of modification account for the impact of slave trade. Enslavement and its demographic impact are known to have been at a high level for many African regions in the nineteenth century. While the export slave trade across the Atlantic ended in the 1850s, exports across the Indian Ocean continued into the 1890s and exports to the Sahara and North Africa continued to 1900. The retention of captives within sub-Saharan Africa, long a by-product of slave exports, grew as a proportion of total enslavement and continued in some regions well past 1900. Assessing the regional flows and the overall magnitude of this nineteenth-century forced migration is an intractable issue, and few serious efforts have been made at quantifying it.(Inikori, Manning, Lovejoy, Cordell, etc.) For instance, up through the eighteenth century, the number of slaves exported from Africa may serve as an adequate index of the overall volume of African enslavement, but this approximation is no longer satisfactory for the nineteenth century.[123] To account for the impact of enslavement, we have prepared matrices for each African territory and each decade from the 1850s through the 1890s, and have made rough estimates of seven variables for each cell:

- numbers enslaved
- mortality upon enslavement
- number of captives retained within the territory
- seasoning mortality of retained captives
- number of out-migrants from the region (mostly captives)
- number of immigrants to the region
- seasoning mortality of immigrant captives

The results of these estimates are then aggregated, compared to the regional population, and expressed as rates to give the figures in the first three categories of modification to growth rates shown in Table 8. That is, *immigration* comes from the number of immigrants; *out-migration* comes from the number of out-migrants; and *slave-trade disorder* comes from the mortality rates of enslavement plus the seasoning mortality of retained and immigrant captives.[124] We have assumed a reduction from base-level growth rate or up to 0.2% per year; such disorder could continue for decades on end.

On immigration, North African territories received slave immigrants until late in the nineteenth century, for which we estimate *that immigration of slaves added to base-level population growth by as much as 0.3% per year. For the equivalent slave-trade out-migration* from sub-Saharan Africa, out-migration rose as high as 0.6% per year. Within sub-Saharan

[123] For the years before 1800, we have assumed that the number of captives retained in sub-Saharan Africa, for each region, was a constant proportion of those exported. After 1850 (and arguably earlier), the proportion of captives retained in Africa rose substantially and there is no obvious basis for estimating their numbers. Manning (citation?)

[124] Additional factors could be added to this estimation, such as the possibility that high proportions of females in slavery might have caused their age-specific birth rates to decline, though the same factor might have increased crude birth rates.

Africa, the flows of captives included those from the West African savanna to Saharan oases, the enslavement of people from the periphery of the great West African states of Sokoto and Samori, and the settlement of slaves along the routes from the Upper Congo and Lake Malawi to the Swahili coast. For regions that exported slaves after 1850, this factor is analyzed in Steps 6 and 7.

The end of slave trade commonly coincided with the colonial conquest, at times ranging from the 1870s to after 1900: see Table A4 for the timing of colonial conquest and the end of slave trade in each territory. Once slave trade ended, the return in security is presumed to have led not only to a decline in death rate but an increase in birth rate. This *post-slave-trade recovery* enabled growth rates to rise from base-level levels by an estimated 0.4% per year for one or two decades.

But colonial regimes, while they brought an imperial peace, also brought their own disorder. Especially for French and perhaps Belgian Central Africa, colonial regimes brought population decline, especially through fertility decline, notably as a result of disease spread in particular by African and European colonial officials. More generally, colonial recruitment of forced labor had negative effects on seasonal production cycles, thus affecting nutrition and mortality. For this type of situation, we project that *colonial disorder* brought reductions in growth rates by as much as 0.3% per year, for periods from a decade to as much as 30 years (see **Appendix B8).** For other colonies, such as West African coastal colonies, *income growth*, especially through expansion of agricultural exports, brought higher fertility, adding to base-level rates by up to 0.2% per year for as long as the boom lasted. Epidemic and famine, finally, could have impacts that brought high mortality, reducing population growth rates by as much as 0.5% per year, but usually for no more than one to three years at a time.[125]

Epidemic and famine, finally, could have impacts that brought high mortality, reducing population growth rates by as much as 0.5% per year, but usually for no more than one to three years at a time.

Having established a typology of varying modifications to the prevailing rates of population growth for each time period, the next step is to apply it and categorize each African region according to the situation it faced in each period. Table 8.4 provides a qualitative summary of the modifications we have made, for each territory and each decade, to the base-level growth rates displayed in Table 8.2. In cases where a cell is left blank, it is assumed that the base-level growth rate for that period is applicable to the region. These estimates, while preliminary and speculative, are at least explicitly identified, to encourage updating based on more thorough evaluation of the descriptive literature for each territory.

[125] Examples included the influenza pandemic of 1918, cholera epidemics of the late nineteenth century in Eastern Africa, and sleeping sickness in Central and Eastern Africa in the early twentieth century.

Table 8.4. Outline of Modifications to Growth Rate

Region	1890s	1900s-20s	1930s-50s
North Africa	c) slave immigration g) free immigration	g) free immigration	
West African savanna	a) slaving disorder b) slave exchanges c) slave emigration	d) post-slaving recovery e) colonial disorder g) free out-migration	g) free out-migration
West African coast	b) slave exchanges d) post-slaving recovery	f) income growth g) free immigration	f) income growth g) free immigration
Central Africa	a) slaving disorder b) slave exchanges d) post-slaving recovery	e) colonial disorder h) epidemic	
Northeast Africa	a) slaving disorder b) slave exchanges c) slave emigration h) epidemic	d) post-slaving recovery e) colonial disorder h) epidemic	
East Africa	a) slaving disorder b) slave exchanges c) slave emigration h) epidemic	d) post-slaving recovery e) colonial disorder h) epidemic	f) income growth
Southern Africa	e) colonial disorder	f) income growth g) free immigration	g) free immigration

Crude-rate analysis of procolonial times. For precolonial times, crude rate analysis is employed in estimating the enslavement of captives held within the continent, in the export of captives to the North and East of sub-Saharan Africa, and in the analysis of Atlantic slave trade. In the latter instance, we seek to match crude-rate figures with composition-specific figures. That is, the demographic simulation calculates composition-specific figures for New Africa Export captive populations, and we scale them up or down to match the total number of Captive Exports estimated in the Bayesian estimation of missing values in voyage-based data for each region and decade.

Composition-specific analysis: Estimating sensitivity and range of variation.

Input data sets, Atlantic and Old World trades. Start with 17 datasets for each region: Source and Captor populations – their absolute and relative size, the Coale-Demeny model chosen; Fertility and mortality rates for default data sets; Captive populations – size, age and sex composition, partition; Captive fertility and mortality rates at various stages. REWRITE

The simulation is a digital model written in the R language, in which such events as birth, death, and enslavement take place continuously but are measured within periods of five years.

This simulation is an electronic implementation of the model described in the previous chapter. COMPARE TO PREVIOUS VERSIONS OF SENSITIVITY? ALSO ADD NOTE TO APPENDIX

Populations are defined within five-year groups, from birth through 4 years, 5 through 9 years, and so forth to a final category of 80+ years. The initial populations are the Captor and Source populations, each with a life expectation at birth of 22.5 years and a growth rate of 0.2% per year. Enslavement takes place each year, and an average **one percent** of the Source population is captured. This raid or other process of enslavement creates, in each period, a Captive population. The Captive population suffers a severe initial mortality, including those losing their lives in the course of capture and those dying as a result of disease and exposure while in captivity. The Captives then undergo a "partition," in which some Captives are retained in Africa while others are destined for sale outside the continent. Those retained in Africa, the New Domestics, are added to the population of Domestic slaves. Those exported undergo another severe mortality, averaging about 15% and corresponding to the Middle Passage; the survivors become New Exports who join the Export slave population in the New World diaspora or the Old World diaspora. Summary of chapter 7

The output from the simulation includes, for each five-year period, statistics with several sorts of dimensions: stocks of population at the end of each period, flows of population per year, cumulative totals of population over a period of years, and various ratios and combinations of these. The output begins with the population by age and sex of the Source, Captor, Domestic, and Export populations, and of Slave Society (the sum of Captors and Domestics) and the African Regional population (Source, Captors, and Domestics). Also calculated for each period are populations of the Captives, New Exports, New Domestics, the number deceased in enslavement, and cumulative totals of these. Finally, the program calculates various ratios of sex and age groups, and rates of birth, mortality, migration, and population growth. REVISE

Since the simulation uses **seventeen** data files on population, fertility, mortality, and migration (each data file consisting, in effect, of a two-by-seventeen matrix), questions immediately arise as to the sensitivity of output to changes in input, and as to interactions among the various input files. **This section** summarizes the results of a sensitivity analysis of interaction effects among input variables.

The sensitivity analysis and calibration begins with our historical window on the issue: the size and composition of the New Exports population, corresponding to the levels of captive exports (by region and by decade), as summarized in Chapter 9. To link this population to the structure of the population remaining in Africa, we must define our *output calibration variable* (E or EXPRATIO) as the ratio of the flow of New Exports to the stock of the African Regional population. This formulation of the analysis requires us, therefore, to estimate the level of African population as a precondition to the analysis. Once such problems are resolved, we emerge with a calibration variable whose projected levels, while not precise, nonetheless have a substantial empirical basis.

Results of the sensitivity analysis on this variable are shown in Table 8.6. Each of **sixteen** input variables was varied over the range of its presumed historical limits. Results, reported in

the right-hand column as contributions to total R-squared (proportion of total variance that is explained by this relationship), indicate the relative importance of input variables in causing variation in the output variable.

Our goal is to study the sensitivity of three dependent variables to changes in the levels of certain independent variables.

Dependent Variables:

1 Export Ratio
2 Growth Rate
3 Adult Sex Ratio MORE ON GROWTH AND SEX?

Independent Variables:

1 Source/Captor Survival Rates
2 Transition Survival Rates
3 Domestic/Export Survival Rates
4 Source/Captor Fertility Rates
5 Transition Fertility Rates
6 Domestic/Export Fertility Rates
7 Amount of Retention via partition array
8 Export Sex Composition implied by partition array
9 Export Age Composition implied by partition array
10 Amount of Capture via capture array
11 Sex Composition implied by capture array
12 Age Composition implied by capture array

We use five different levels for each of the independent variables, which are generated by modifying the default arrays as follows:

Table 8.5. Modifications to Default Arrays

Variable	**Levels**	**Modifications to Default Arrays to Obtain Levels**
1	1,2,3,4,5	Multiply Source/Captor Survival by .96, .98, 1, 1.02, and 1.04
2	1,2,3,4,5	Multiply Transition Survival by .96, .98, 1, 1.02, and 1.04
3	1,2,3,4,5	Multiply Domestic/Export Survival by .96, .98, 1, 1.02, and 1.04
4	1,2,3,4,5	Multiply Source/Captor Fertility by .96, .98, 1, 1.02, and 1.04
5	1,2,3,4,5	Multiply Transition Fertility by .96, .98, 1, 1.02, and 1.04
6	1,2,3,4,5	Multiply Domestic/Export Fertility by .96, .98, 1, 1.02, and 1.04
7	1,2,3,4,5	Multiply Partition Array by .96, .98, 1, 1.02, and 1.04
8	1,2,3,4,5	Multiply women\men in Partition Array by 1.1\.9, 1.05\.95, 1\1, .95\1.05, and .9\1.1
9	1,2,3,4,5	Multiply 0-10\30-40 in Partition Array by 1.1\.9, 1.05\.95, and 1\1; Multiply 0-10\40-50 in Partition Array by .95\1.05 and .9\1.1
10	1,2,3,4,5	Multiply Capture Array by .8, .9, 1, 1.1, and 1.2
11	1,2,3,4,5	Multiply women\men in Capture Array by 1.25\.75, 1.1\.9, 1\1, .9\1.1, and .75\1.25
12	1,2,3,4,5	Multiply 0-10\30-40 in Capture Array by 2\.5, 1.5\.75,1\1, .75\1.5,

		And .5\2

We attempted to capture the equal spacing of the levels 1-5 in the way we modified the default arrays, e.g. in equal increments of 2% in survival and fertility rates. Furthermore, we attempted to modify partition and capture arrays to generate variables 7-9 and 10-12 in such a way that modifying the array only has an impact on the actual levels of the desired variable. For example, default source population and capture rates are both roughly equal across gender, therefore multiplying the array by .8, .9, 1, 1.1, and 1.2 to obtain the levels of capture size for variable 10 will not have a great impact on the levels of the capture sex ratio in variable 11 or capture age ratio in variable 12. Modifications also had to be constructed so as not to violate logical bounds. For example, multiplicative adjustments to the partition array can not result in a partition rate greater than 1 for any combination of age and gender.

We use the sample function in our programming language to randomly generate a collection of levels for each of the 12 independent variables. After making the corresponding modifications to the default arrays, we run the simulation program for 40 years, and record each of the three dependent variables. We repeat this procedure to obtain many different combinations of levels of independent variables and the corresponding values of dependent variables

Before attempting to quantify the relationship between the dependent and independent variables, we impose admissibility criteria as follows:

1 Proportion of exports who are female must be between .3 and .4
2 Proportion of exports between ages 0 and 20 must be between .2 and .3
3 Export ratio must be between .002 and .01

Any combination of independent variables that yields output which fails to satisfy all three criteria is discarded as inadmissible. We then take the remaining collection of admissible combinations of independent and dependent variables and regress each of the dependent variables on the independent variables. We take—as our measure of the sensitivity of a dependent variable to a given independent variable—the amount of variation in the dependent variable explained by that independent variable. Results of the analysis for each of the three variables are as follows:

Table 8.6. Sensitivity Analysis: Dependent Variable EXPRATIO

DEPENDENT VARIABLE: EXPORT RATIO	**R^2**
Source/Captor Survival Rates	.0002
Transition Survival Rates	.0138
Domestic/Export Survival Rates	.0000
Source/Captor Fertility Rates	.0001
Transition Fertility Rates	.0024
Domestic/Export Fertility Rates	.0000
Amount of Retention via partition array	.6349
Export Sex Composition implied by partition array	.0000
Amount of Capture via capture array	.0001
Sex Composition implied by capture array	.2599

Age Composition implied by capture array	.0279
Source/Captor Survival Rates	.0468
TOTAL	.9562

The results of this analysis indicate that the main determinants of E are the sex composition of capture and the nature of the partition of captives into domestic and exported slaves. Other measurable effects are provided by the size of the raid, the mortality of captives and the mortality of the general African population. EXPAND

The next step in calibration is to establish historical limits on the size and composition of the stream of New Exports: limits which, by extension, restrict the levels of input data for the variables shown in Table 8.6. The levels of E are set, for each time period, as ratios of documented totals of slave exports to projected levels of African Regional population. In addition, two parameters are set for all times to limit the age and sex composition of simulated New Exports populations. **For sex, the ratio of female New Exports to total New Exports is kept in the range from 0.3 to 0.4. For age, the ratio of New Exports aged 0-17 to total New Exports is kept within the range from 0.2 to 0.3.** The combination of these output calibration factors serves to restrict the range of permissible input combinations. REPETITION?

With output calibration well under way, we may turn to the two major *output prediction variables*. These variables—the African Regional growth rate (G or GROWTH) and the ratio of women to men of marriageable age in Slave Society (S or SEXRATIO)—are not directly observable from historical data in the E is. The research design, however, is to seek out correlations among the determinants of all three output variables, so that we may use documented levels of E to project historical levels of G and S. This requires equivalent sensitivity analyses for the two output prediction variables.

Table 8.7 shows that the resultant African growth rates, under the impact of slave exports, correlate primarily with mortality rates of African populations. Growth rates correlate only secondarily with **certain slave-trade variables: the size, sex, and age composition of capture**. This result, which prevents us from saying that slave trade determined the rate of African population growth, nonetheless **permits us to argue below that net African growth rates were negative in the slave-trade era unless the intrinsic African growth rate was greater than one percent per year.**

Table 8.7. Sensitivity Analysis: Dependent Variable GROWTH

DEPENDENT VARIABLE: GROWTH RATE	**R^2**
Source/Captor Survival Rates	.9355
Transition Survival Rates	.0012
Domestic/Export Survival Rates	.0001
Source/Captor Fertility Rates	.0126
Transition Fertility Rates	.0015
Domestic/Export Fertility Rates	.0002
Amount of Retention via partition array	.0131

Export Sex Composition implied by partition array	.0026
Amount of Capture via capture array	.0000
Sex Composition implied by capture array	.0175
Age Composition implied by capture array	.0184
Source/Captor Survival Rates	.0017
TOTAL	.9974

For the sex ratio in Africa, on the other hand, we find that the main correlates of SEXRATIO are almost identical to the determinants of EXPRATIO, and in almost the same relative importance: these are the variables defining the size and composition of enslavement and of the partition between domestic and exported slaves. We may thus hope to predict the African sex ratio from what we know about the composition of the New Export slave populations.

Table 8.8. Sensitivity Analysis: Dependent Variable SEXRATIO

DEPENDENT VARIABLE: SEX RATIO	**R^2**
Source/Captor Survival Rates	.0000
Transition Survival Rates	.0004
Domestic/Export Survival Rates	.0001
Source/Captor Fertility Rates	.0017
Transition Fertility Rates	.0000
Domestic/Export Fertility Rates	.0006
Amount of Retention via partition array	.0080
Export Sex Composition implied by partition array	.8506
Amount of Capture via capture array	.0011
Sex Composition implied by capture array	.0001
Age Composition implied by capture array	.0781
Source/Captor Survival Rates	.0016
TOTAL	.9186

We may check the logic and consistency of the assumptions by combining results of these three tables. For example, if we could decrease the proportion of women captured and also increase the proportion of women exported, we could recalibrate EXPRATIO and project a more even African sex ratio and greater African growth rate. But the evidence against making such a change in assumptions includes the consistent excess of female slave prices over male slave prices in African slave markets, and the qualitative accounts attesting to the large number of female slaves in Africa. EXPAND

Composition-specific Strategy for Projecting Populations, 1650 – 1890.

Back-projections for population and migration from 1890 back to 1650 rely on a combination of three types of estimates of the number of persons enslaved. In times before 1790, the proportions of captives retained and exported are given in the Partition function, so that the simulation predicts at once the African population and the number of enslaved Domestic and Export captives for the preceding decade. In times after 1790, however, we identify the decade of

the peak in slave exports for each African region. In times after that peak, when the number of export captives declined, it is assumed that the total number of persons captured remained unchanged until the 1880s. This adjustment to the assumptions requires a more complex procedure of applying the simulation, which is now described.

This description of the procedure shows the steps for moving from the 1850 population to the 1840 population. It is based on 40-year simulation,where PSim is simulation population, PHst is historical population, MSim is simulation migrant flow, and MHst is historical migrant flow.

1.Begin with input files, including PSim.src.1810 and PSim.cap.1810

2.Run simulation 1810-1850, and get results: PSim.reg.1850 and MSim.NewExp.1840s

3.Locate 1850 Historical population PHis.reg.1850.

4.Locate 1840s Historical migration MHis.NewExp.1840s

5.Calculate **Population Scale = R1** = (PHist.reg.1850)/(PSim.reg.1850)

6.Calculate **Export Scale = R2** = (MHist.NewExp.1840s)/(MSim.NewExp.1840s)

7.Calculate **Capture Intensity = F = R2/R1 = (Export Scale)/(Population Scale)** =

$$\frac{[(\text{MHist.NewExp.1840s})/(\text{MSim.NewExp.1840s})]}{[(\text{PHist.reg.1850})/(\text{PSim.reg.1850})]} = \frac{[(\text{MHist.NewExp.1840s})/(\text{PHist.reg.1850})]}{[(\text{MSim.NewExp.1840s})/(\text{PSim.reg.1850})]}$$

8.Multiply capture file by F.

9.Run simulation 1810-1850 with capture file modified by F, and get results:

PHis.reg.1840. The simulation should also reproduce PHis.reg.1850, MHis.NewExp.1840s.

10.Repeat procedure to obtain 1830 population, running simulation 1800-1840, etc.

Note that, in this procedure, schedules for capture and partition are adjusted separately, based on assumptions drawn from the historical literature.

Error margins

Finally, our analysis includes modeling the estimation of error margins, to assess the dependability of all quantitative demographic estimates. At the most basic level, we have the responsibility to make speculative error estimates for synthetic estimates of data (usually migration) in crude-rate estimates. Second, we must find a basis for estimating the mean-projection, voyage-based estimates of Atlantic migration. Third, we present the Bayesian error estimates for crude-rate population estimates, mostly after 1890. Fourth, we define and present error estimates for composition-specific population estimates, mostly before 1980. Fifth, we present the Bayesian error estimates for missing data in estimates of Atlantic migration.

[Note: this error discussion focuses on the crude-rate analysis, not yet on the composition-specific analysis.]

The sources of possible error are numerous for estimates of this complexity, and good demographic practice requires explicit discussion of them. To begin with, there may be systematic errors in the model of demographic reasoning. These would present a serious error, but could be readily corrected once identified.[126] While the populations estimated for each decade do not specify age and sex distributions, the analysis is otherwise relatively disaggregated (especially by region) and thus provides protection against the most obvious systematic errors.

Second, there are possible errors in data, where the data employed in this analysis differ from the unknown true values of the variables. The setting of base-level growth rates by using Indian data as proxies introduces possible error of this type, both because the figures used for Indian growth may be in error and because the true African growth rates surely differed in greater or lesser degree from those of India. The compounding of hypothesized growth rates—going backward in time for ten successive decades— inevitably magnifies errors, especially errors in more recent times.[127] The revised growth rates—modifications of base-level growth rates based on a number of relevant factors—may improve accuracy for the most part yet still introduce inaccurate data for many or all of these factors. For instance, the estimates of fertility increase occurring at the end to slave trade and in periods of increasing income, while plausible in principle, are not known through empirical data. For migration, especially through domestic and export slave trade, the estimates are complex and difficult to verify; one must prepare these estimates carefully to avoid double-counting migrants or the mortality resulting from migration.

If the internal logic of the estimates holds up, it is still necessary to seek ways to verify or falsify them empirically. The search for additional data is the most obvious approach to such verification: in particular, if one could locate small and well-documented African populations for the period 1890-1950, their rates of birth, death, migration, and population growth would be important aids to verification. A second strategy for verification is thorough comparison of birth and death rates elsewhere in the world in the period 1890-1950.

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[126] Details of the program are available on the "Migration Simulation" website, www.worldhistorynetwork.org/migrationsim.

[127] An example of errors specific to the late nineteenth century results from the large proportion of captives retained in Africa in that era. In earlier times, the relatively secure documentation of overseas slave exports gave a clear basis for estimating disruption on the continent. But with the decline of slave exports after 1850, the paucity of data on the magnitude of continental slave trade means that the error margins of estimates increase.

This study has added a third method for estimating colonial African populations to those already in use. That is, it has added back-projection by hypothesized crude growth rates to the method of continental speculation (sometimes from first principles) and the method of revision and aggregation of colonial records. The most impressive set of methods has been that used by the United Nations Population Division for the period after 1950, assembling and collating the full range of demographers' work, and steadily updating the estimates in a consistent framework. Resources for the study of colonial and precolonial populations will of necessity be far more meager, but perhaps the practices of population analysis for postcolonial years can be applied on a more modest scale.

Having discussed possible errors in qualitative terms above, we now turn to quantitative measures of the error in our population estimates. We utilize backward projection methodology to arrive at population estimates for each region and for each decade from 1940 back to 1890. These regional estimates are obtained using the assumed base-level growth rates in Table 7, the choices of which were guided by considering relatively well-documented Indian growth rates during the same timeframe. In an attempt to address the error introduced by differences between these base-level rates and the actual true unknown African rates, we also project backwards using low (high) level growth rates obtained by adding (subtracting) 0.1% per year from the base-level rates. We simply sum the regional estimates of population at the low, mid, and high rates to yield the continental totals depicted in Figure 4. As we can see, this method results in error bounds that become wider over time, and yields a continental estimate of roughly 149 million +/- 10% for 1850.[128] In addition, using the revised (and presumably more accurate) growth rates outlined in Table 8, we project back in an analogous manner. This approach yields a mid-level continental population of 149 million for 1850, with 135 million and 163 million as the corresponding low and high estimates.

Inasmuch as the above methodology provides a very simple framework for obtaining estimates of error intervals, the validity of the center and spread of those estimates depends greatly on the base-level growth rates and the manner in which we allow those rates to fluctuate when constructing low and high level estimates. The modified Indian growth rates along with the situation adjustments should provide a reasonable starting point and hence yield a reasonable center for the interval estimate. However, the manner in which true rates may have differed from the revised rates is not well captured by simply adding or subtracting 0.1% per year to each growth rate. Nevertheless, we can establish the conservative nature of this interval estimate by showing that the magnitude of the spread is even smaller when we incorporate a more realistic departure from the base-level rates.[129]

For a given region and decade, we can assume that the true unknown growth rate is equal to the corresponding revised growth rate plus an error term randomly drawn from some probability distribution. Choosing this distribution introduces some degree of subjectivity, therefore we work under another conservative assumption. We assume uniformly distributed error distributions (of annual growth rates per thousand) centered at zero and ranging from -10 to

[128] Adding or subtracting 0.1% to the annual growth rate for each of 100 years yields high and low estimates 10% different from the default rate for 1850.

[129] By "conservative" estimate of the error we mean an estimate that gives a relatively wide estimate of the spread from minimal to maximal estimates of growth rates and of population.

10. Recall the revised rates are per thousand, so this essentially allows for the simulated rates to vary from the base-level rates by as much as 1%, rather than by only 0.1% in the approach described above. For example, if we specify a given revised rate as 5 per thousand, this tolerance allows the rate we actually use in calculations to vary between -5 and 15 per thousand. Using the uniform distribution means that any value in this interval is equally likely, which reduces the impact of inevitable deviations between assumed and true rates.[130]

Using the statistical software package S+, we obtain a value to use as a growth rate by simulating a single value from this distribution and adding it to the assumed growth rate for each region and each decade. We carry out the same procedure across all decades and regions to get a collection of growth rates that can subsequently be used to project initial 1950 populations back to 1890.[131] Finally, we carry out the procedure 100,000 times to obtain what amounts to the Monte Carlo distribution of the continental population under our assumptions. The sample 5th percentile, median, and 95th percentile of the distribution for a given decade serve as low, mid, and high level estimates, respectively. Using the revised growth rates, these estimates are roughly 134 million, 142 million, and 151 million for 1850.[132] The center of this interval estimate is very similar to the center obtained under the fixed +/-0.1% revision method, whereas the width of the interval is reduced nearly by a factor of two.

Other error issues – margins in composition-specific projection, in Atlantic missing values, in capture and export generally.

Conclusion

Estimated links of independent and output variables (From regression analysis, show proportion of growth change for each male or female exported, etc.)

Additional variables: drought, famine, and war (Model and estimate how these fit into the overall process).

The results of this analysis confirm, most importantly, that the most significant variable is the level of mortality in African free populations, and the associated levels of mortality in the migrant and slave populations stemming from free Africans. This is a topic on which detailed evidence is particularly lacking, and where assumptions are all the more important. More broadly, the variables identified as significant in the sensitivity analysis reconfirm the earlier estimates, although details of the model and of the data included in it have changed measurably.

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[130] If we wanted to exude more confidence in our default rates, using a normal error distribution would place more likelihood on rates close to our revised rates, and less likelihood on rates further away. A normal error distribution in fact yields interval estimates tighter than those presented here.

[131] We generate the rates for all decades and regions independently of one another. As a future consideration, a better assumption is to allow for a correlation structure within the simulated rates, e.g. from decade to decade within a given region and/or from region to region within a given decade.

[132] As shown in Table 12. Note that the relative size of the error margin, as shown in Table 12, is smaller for Africa as a whole than for its sub-regions. This is because the number of observations is larger for the continent as a whole than for any of its constituent regions: in effect, the regional errors tend to cancel out for the continent as a whole.

Chapter 9.

Migration of Captives: New Estimates

"Multiple Perspectives" and "Voyage-based" Approaches to Migration Data
Voyage-based analysis: Mean-projection estimates
Voyage-based analysis: Bayesian estimates
"Multiple Perspectives" Modeling of Captive Migration
Error Margins
Conclusion

Here we report a full set of new quantitative estimates of the volume of captive enslavement and migration within Africa and for the external slave trade of Sub-Saharan Africa. We provide estimates first for the transatlantic slave trade; then for the export slave trade across the Saharan, the Red Sea, and the Indian Ocean; and finally for the level of continental enslavement, especially for the nineteenth century. The newly proposed totals for the transatlantic slave trade and for the Indian Ocean slave trade are significantly higher than those previously reported. The totals are higher for two reasons: (1) because new research has located expanded evidence of slave trade for both the Atlantic and the Indian Ocean and (2) because existing documentation on the Atlantic slave trade, when processed with advanced techniques, yields higher estimates of the volume of slave trade.

"Multiple Perspectives" and "Voyage-based" Approaches to Migration Data

As noted in Chapter 7, we have organized the range of data on captive migration into two categories: those developed through "multiple perspectives" and those that are "voyage-based." The multiple-perspectives data include a wide range of documents, often qualitative rather than quantitative. The voyage-based data are more often quantitative and are reported in the context of specific voyages of transatlantic ships understood to be participating in slave trade. We focus first on the voyage-based data and turn later to the multi-perspectival data.

The point is that data on slave voyages had *missing data* for a substantial number of captives – usually a majority. What methods were used to estimate the missing data?

Two methods for estimating missing data: the "mean-projection" estimates developed especially by David Eltis, which have been the principal estimates of transatlantic slave trade volume and direction since 1999, and the "Bayesian" estimates that are introduced here as an

alternative approach relying on more advanced statistical and computational methods. In the two sections below we describe the details of the two approaches, to establish their similarities and differences. Later in the chapter, summaries of the two sets of results are presented and compared.

Voyage-based analysis: Mean-projection estimates

David Eltis and his colleagues followed a process of "mean-projection estimates" to work from available data on captive emigration to an estimate of the total. Eltis, from the time of his earliest work on the 1845 Parliamentary Paper on the Atlantic slave trade, proposed "imputations" of missing data on captives. The basic approach was to calculate mean numbers of captives known to have been transported on certain voyages, and to attribute that same mean to the missing numbers of captives on other but similar voyages. (Give an example or so from his G&H article and his Atlantic book.) These estimates, which appeared plausible although the precise method of their calculation was not always presented, gained a substantial authority with time. An extension of this same approach was adopted in the 1999 and 2008-2010 editions of the Atlantic Slave Trade Database. We propose to label these as "mean-projection estimates." We note that one limitation of these estimates is that they give no estimate of the dependability or the error margin of the numbers projected.

Figure 9.1. Categories for Mean-projection estimates

Number embarked per voyage	5081	
Number disembarked per voyage	10708	
Number Emb & Disemb	6884	
Embarkations unspecified	756	
Disembarkations unspecified	5483	
Assumed slave ships	2788	
Voyages	31,700	

In general, for groups of voyages (separated by European port of departure, African port of departure, American port of disembarkation, and vessel tonnage), an average number of captives is attributed, and these totals are then aggregated by region and by decade.

Tools for imputation:

- **Death ratios** at sea are imputed using Table 2 (pg 19), with average % mortality calculated as (deaths/embarkations) per voyage for either 5704v or 5300v with both deaths and embarkations – calculated for the whole period from 1527 to 1866. (By the way, Eltis assumes death rates were unchanging by age or sex. That has been your assumption too. We can get away with it only if the age/sex distribution of captives varies little.)
- **Average disembarkations** [for voyages beginning in Europe or Brazil, but calculated separately for each African region of embarkation] are imputed using Table 4 (pg 21) with mean numbers of disembarkations for captives embarked in each African region – calculated for the period 1527-1866.

Steps in imputation, using the above tools:

A. Small ships that began their voyage in North America or the Caribbean are assumed to have carried a consistent average of 137.3 captives (I think this means disembarked, but it might mean embarked)
B. For ships beginning their voyage in Europe and Brazil, they are imputed the average number disembarked by African region of embarkation (Table 4); they are imputed a % mortality (and number of deaths) from Table 2, and are imputed the resulting number of embarkations.
C. For the 756v lost from the record, it is assumed that all arrived in the Americas. They are imputed the mean number disembarked by African region of embarkation, and are imputed embarkation by the % mortality by region of embarkation.
D. For the 2788v with identified or intended African region of trade, they are imputed as above with Tables 2 and 4. (But I'm not sure how the American region of arrival is known, unless it is from ships' orders.)
E. For the U.S.A. north of Maryland, all voyages are assumed to have 73.8 captives embarked and 64 disembarked.

Thereafter, pages 21-22 discusses the cases where embarkation or disembarkation took place in multiple regions, and develops rules for allocating captives among regions.

Voyage-based analysis: Bayesian estimates

Meanwhile, in work conducted in the project underlying this book, a set of "Bayesian estimates" was calculated. These estimates are 20% higher, in general, than the mean-projection method. Where do the two methods vary more or less than 20%?

We assume that we accept the Eltis regions (except for our split of West Central Africa at the Congo River). Second, I assume we accept the decade (at the margin, the date) that Eltis assigned to each voyage. (my notation: 2v = 2 voyages):

Here, as for the "mean-projection estimates," various categories of data combinations are selected, and estimation methods are selected to fit them

Figure 9.2. Categories and Types of Bayesian Estimates

	Port w/ Decade	Decade w/o Port	Port w/o Decade	Neither
Embarkation	Direct estimate	Multinomial	Multinomial	Multinomial
Arrive w/o embark	Ratio & SAE	Ratio & Multinom.	Radio & Multinom.	Ratio & Multinom.
Neither	Mean & SAE	Mean & Multinom.	Mean & Multinom.	Mean & Multinom.

Where: SEA = small-area estimation; Ratio = ratio estimate; Multinomial = propagation through the nultinomial model; Mean = using the mean as an estimate

These methods are described in fuller detail in Appendix F.

Figure 9.3, part 1. Bayesian estimates and "Slave Voyages" estimates of missing and total Atlantic embarkations of captives

File name: MCMC_MI
Date: 08/04/2013
Note: Use Markov chain Monte Carlo (MCMC) to create multiple imputation

Region	1650tot	1660tot	1670tot	1680tot	1690tot	1700tot	1710tot	1720tot	1730tot	1740tot	1750tot
SENEGAMBIA AND OFFSHO	11,116	14,541	7,307	14,594	19,512	8,425	22,333	37,652	51,065	29,250	54,794
SIERRA LEONE	-	506	-	1,438	3,426	2,912	1,981	5,268	1,322	3,194	14,159
WINDWARD COAST	98	-	-	527	-	2,799	1,595	3,464	2,443	14,672	25,966
GOLD COAST	594	9,535	28,967	9,398	45,980	101,700	96,726	102,387	81,332	52,597	84,912
BIGHT OF BENIN	11,187	23,943	19,686	72,937	77,975	111,293	124,094	140,265	155,646	109,914	89,488
BIGHT OF BIAFRA	5,090	17,774	19,870	17,905	10,186	12,813	23,901	14,137	35,689	74,496	77,317
Gabon	834	3,578	2,771	2,523	13,774	819	9,503	3,831	12,453	11,681	7,087
Loango	624	5,643	14,091	5,390	22,507	34,191	17,943	46,561	54,102	58,089	59,364
Angola	18,533	5,817	12,892	22,098	56,182	35,323	30,807	122,519	162,085	183,433	102,045
West Cemtral Africa	*19,157*	*11,460*	*26,983*	*27,488*	*78,689*	*69,514*	*48,750*	*169,080*	*216,187*	*241,522*	*161,409*
Southeast Africa and Indian	-	1,078	1,409	5,951	2,527	166	7,066	8,007	156	-	-
Other Africa	-	262	259	-	95	4,331	3,788	8,909	5,508	19,489	19,395
sum	**48,076**	**82,677**	**107,252**	**152,761**	**252,164**	**314,772**	**339,737**	**493,000**	**561,801**	**556,815**	**534,527**

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Eltis, 2010: Slave Voyages imputed total for slave embarkations by African region of departure
Note: "West Central Africa" has been divided into "Loango" and "Angola" by ports north and south of the Congo River

	1651-60	1661-70	1671-80	1681-90	1691-1700	1701-10	1711-20	1721-30	1731-40	1741-50	1751-60
Senegambia and offshore	17,723	6,407	13,267	21,927	22,558	16,344	22,669	34,993	44,816	24,210	50,555
Sierra Leone	752	154	-	1,894	2,671	1,217	3,114	9,419	1,468	8,004	17,419
Windward Coast	351				999	3,059	4,365	4,532	9,392	25,202	44,083
Gold Coast	1,437	19,193	28,835	16,274	40,443	81,144	97,287	113,877	106,723	61,626	88,174
Bight of Benin	12,163	29,926	29,813	79,890	108,412	136,943	149,463	194,430	145,805	108,220	122,566
Bight of Biafra and Gulf o	24,791	37,668	34,394	21,709	31,299	21,979	34,615	41,830	56,583	93,891	93,294
West Central Africa	*95,382*	*126,758*	*108,966*	*109,373*	*130,939*	*133,434*	*131,867*	*145,989*	*231,989*	*245,436*	*223,830*
SoutheastAfrica	3,088	9,432	7,116	9,497	2,237	120	10,029	3,934	1,226	-	3,036
sum	**155,687**	**229,538**	**222,391**	**260,564**	**339,558**	**394,240**	**453,409**	**549,004**	**598,002**	**566,589**	**642,957**

Figure 9.3, part 2. Bayesian estimates and "Slave Voyages" estimates of missing and total Atlantic embarkations of captives

File name: MCMC_MI
Date: 08/04/2013
Note: Use Markov chain Monte Carlo (MCMC) to create multiple imputation

Region	1760tot	1770tot	1780tot	1790tot	1800tot	1810tot	1820tot	1830tot	1840tot	1850tot	1860tot	Total
SENEGAMBIA AND OFFSHOR	50,786	44,714	34,704	26,842	26,944	19,583	9,441	3,035	6,908	150	650.0	494,346
SIERRA LEONE	41,905	28,033	34,992	44,241	34,609	8,089	24,256	29,703	31,473	2,881	-	314,388
WINDWARD COAST	53,302	43,299	23,162	17,411	14,863	5,118	4,139	5,733	163	-	-	218,754
GOLD COAST	82,762	87,264	117,782	89,243	61,334	3,177	2,219	913	-	700	-	1,059,522
BIGHT OF BENIN	102,405	113,712	91,523	85,964	90,450	60,576	50,449	54,623	153,368	39,772	9,195.0	1,788,465
BIGHT OF BIAFRA	123,323	82,622	137,573	138,541	91,563	37,939	68,731	38,967	2,391	2	1,970.0	1,032,800
Gabon	14,665	10,646	21,883	34,837	11,503	24,645	7,900	18,679	25,167	1,200	-	239,979
Loango	83,120	69,547	65,230	43,917	72,198	173,113	207,205	62,677	124,504	129,475	50,147.0	1,399,638
Angola	167,895	140,606	185,606	308,735	284,335	273,382	309,419	197,926	266,108	32,856	3,355.0	2,921,957
West Cemtral Africa	*251,015*	*210,153*	*250,836*	*352,652*	*356,533*	*446,495*	*516,624*	*260,603*	*390,612*	*162,331*	*53,502*	*4,321,595*
Southeast Africa and Indian c	47	3,214	43,987	12,074	46,933	109,603	145,019	133,785	43,060	51,433	577.0	616,092
Other Africa	33,860	30,970	36,524	5,703	7,968	662	3,577	5,482	2,556	1,605	1,183.0	192,126
sum	**754,070**	**654,627**	**792,966**	**807,508**	**742,700**	**715,887**	**832,355**	**551,523**	**655,698**	**260,074**	**67,077.0**	**10,278,067**

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Eltis, 2010: Slave Voyages imputed total for slave embarkations by African region of departure
Note: "West Central Africa" has been divided into "Loango" and "Angola" by ports north and south of the Congo River

	1761-70	1771-81	1781-90	1791-1800	1801-10	1811-20	1821-30	1831-40	1841-50	1851-60	1861-70	-
Senegambia and offshore /	52,405	51,267	37,944	28,043	53,702	29,166	13,073	4,626	8,375			554,070
Sierra Leone	42,296	36,551	31,378	51,119	42,627	22,624	43,543	43,926	21,023	4,795		385,994
Windward Coast	76,521	65,186	36,067	21,176	25,241	7,190	7,867	3,155				334,386
Gold Coast	108,658	112,562	135,036	109,441	75,746	1,712	5,362	3,293				1,206,823
Bight of Benin	110,383	109,887	113,692	93,197	95,428	74,093	59,250	73,081	108,943	22,528	11,339	1,989,452
Bight of Biafra and Gulf of	146,542	109,997	151,242	154,642	140,385	65,870	163,525	97,829	27,554	2		1,549,641
West Central Africa	*280,240*	*267,293*	*333,888*	*371,789*	*339,975*	*407,491*	*441,968*	*343,464*	*387,008*	*113,927*	*42,852*	*5,013,858*
SoutheastAfrica	1,916	2,924	28,746	19,000	50,450	77,697	121,158	116,910	43,640	30,167		542,323
sum	**818,961**	**755,667**	**867,993**	**848,407**	**823,554**	**685,843**	**855,746**	**686,284**	**596,543**	**171,419**	**54,191**	**11,576,547**

At this point, the Bayesian estimates of Atlantic slave exports, while working from the same basic data as the mean-projection estimates, yield a total that is approximately 88% of the mean-projection estimates. The largest proportional differences between the two are for the seventeenth century, where the mean-projection estimates are higher, and for the period after 1840, where the Bayesian estimates are higher. It will require a detailed comparison of the two approaches to determine the reasons for these estimates. Such a comparison will require a fuller disclosure of the methods by which each set of estimates has been developed. For now, We will go ahead and use the new, Bayesian estimates, on the argument that they rely on a more sophisticated, statistically supported, reasoning for analysis.

In addition, since we do not now have (and are unlikely every to find) parallel voyage-based information for the export of slaves to the north and east of sub-Saharan Africa, we must take the above discrepancy between mean-projection estimates and Bayesian estimates of missing values as indication of how substantial the range of error may be in our existing multiple-perspective estimates of slave exports from various parts of the African continent.

"Multiple Perspectives" Modeling of Captive Migration

As noted in Chapter 7, with the exception of voyage-based data, African migration is often documented in vague, general, and qualitative terms. The task of developing quantitative estimates out of these documents is complex, and involves using varied and eclectic techniques. First we work on the export of captives from northern and eastern Africa. Then we turn to estimating levels of enslavement and retention of captives within Africa from 1650 to 1900, focusing especially on the nineteenth century.

Export of Captives from Northern and Eastern Africa. Table 9.4 gives an explicit and region-by-region quantitative summary of decennial exports of sub-Saharan African captives from 1650 to 1900. These figures have been drawn up principally by summarizing the estimates of Austen and others, as presented in Chapter 2 above. They are not greatly different from those first proposed in Manning (1990), but the total is larger especially because of the additional research on Indian Ocean slave trade, especially through the work of Gwyn Campbell.

Table 9.4. Decennial estimates of slave exports, Northern and Eastern Africa
Source: Austen, other sources as listed.

Region	W. Sudan	C. Sudan	E. Sudan	Horn	Kenya	Tanzania	Moz (Atl)	Moz (Ind. O.)	Mad
1650	3,025	1,650	4,620	3,800	-	800		1,200	
1660	3,025	1,650	4,620	3,800	-	800	99	1,200	
1670	3,025	1,650	4,620	3,800	-	800	239	1,200	3,531
1680	3,025	1,650	4,620	3,800	-	800	678	1,200	3,531
1690	3,025	1,650	4,620	3,800	-	800	183	1,200	3,531
1700	3,025	1,650	4,620	3,800	-	800	6	1,200	3,531
1710	3,025	1,650	4,620	3,800	-	800	467	1,200	3,531

1720	3,025	1,650	4,620	3,800	-	800	351	1,200	3,531
1730	3,025	1,650	4,620	3,800	-	800	43	1,200	3,531
1740	3,025	1,650	4,620	3,800	-	800		1,200	3,531
1750	3,025	1,650	4,620	3,800	-	800	161	1,200	3,531
1760	3,025	1,650	4,620	3,800	-	800	223	1,200	3,531
1770	3,025	1,650	4,620	3,800	-	800	294	1,200	1,155
1780	3,025	1,650	4,620	3,800	-	800	2,871	1,200	1,155
1790	3,025	1,650	3,520	3,800	-	800	1,464	1,200	1,155
1800	4,950	8,400	3,520	3,900	-	3,000	4,291	5,000	1,500
1810	4,950	8,400	4,620	4,300	-	14,000	6,845	12,000	4,160
1820	4,950	8,400	10,120	4,300	-	20,000	11,238	20,000	2,000
1830	4,950	5,600	10,120	4,300	-	30,000	7,784	20,000	3,000
1840	4,950	6,400	6,820	4,300	-	20,000	1,967	15,000	3,500
1850	4,950	8,000	4,620	4,300	-	20,000	1,213	20,000	4,000
1860	3,850	6,000	23,100	4,300	-	18,691		15,000	4,000
1870	3,850	4,200	3,300	4,200	-	20,000		8,000	4,000
1880	1,100	4,200	550	4,050	-	10,000		20,000	4,000
1890	-	3,100	550	600	-	9,000		5,000	4,250

Enslavement and migration of captives within Africa. The accounting for all the types of demographic impact of enslavement requires tracing all the flows of captives, in all directions, and all the categories of mortality of captives. For flows of captives, one must distinguish those remaining in the region of their captivity, those sent beyond sub-Saharan Africa, those sent out of the region of their captivity, and others brought from other regions into the region under study. These captive flows are displayed in Table 9.5. For flows of mortality, one must consider mortality on capture, the various rates of mortality for captives during their transportation, the "seasoning" mortality as captives are settled at their destination—and ultimately the normal mortality of settled slaves.

Table 9.5. Types of Captive Flows

Flows in absolute numbers (each with an associated mortality)	**Flows in terms of rates (with associated mortality rate)**
Captives	Rate of capture
Retained captives	Rate of retention
Out-migrants beyond sub-Saharan Africa (captive exports)	Rate of out-migration beyond SSA
Out-migrants within sub-Saharan Africa (continental captive migrants)	Rate of out-migration within SSA
In-migrant captives	Rate of captive in-migration
	1 yr high mortality for retained captives
	1 yr high mortality for SSA captives
	2 yrs high mortality for beyond SSA

To repeat, these factors need to be accounted for, one way or another, in any formulation of the model for estimating the demographic impact of continental and export enslavement.

In practice, however, the shortage of data makes it impractical to try to keep track of so many factors at once. For work at this stage, we have chosen to rely on three simple variants of our demographic model to give a range of estimates of the volume and social impact of enslavement within the African continent.

The first, Variant 1, gives a low estimate of the impact. It assumes that continental enslavement can be explained as a by-product of the export slave trade. According to this variant, continental enslavement was essentially a "by-product" of the export slave trade. That is, the number of persons enslaved and held within the continent was roughly equal to the number enslaved and sent beyond sub-Saharan Africa in captivity. In this case, as the number of slave exports declined, so also did the number of persons enslaved and held on the continent. According to the basic simulation model that is applied to the eighteenth and early nineteenth centuries, each of the annual levels of exports brings enslavement of a roughly equal number of persons who remain within Africa. We argue that Variant 1 gives a good estimate of the experience of the seventeenth and eighteenth centuries, in which continental African enslavement expanded along with the export slave trade. Variant 1 projects that the total number of persons enslaved in Africa, by decade, was roughly twice that given by the number of captives exported across the seas or the desert. Since the number of slave exports declined steadily from the 1830s, this approach suggests that the total number enslaved declined at the same rate. Such an assumed steady relationship between continental and export slave trades broke down in the nineteenth century, however, as export slave trade declined in region after region, while continental slave trade maintained itself or even expanded.

Variant 2 assumes that enslavement expanded in response to the demand for slaves beyond the African continent, but that a sort of habit had formed and that the level of enslavement remained unchanged even when the external slave trade declined. As a result, the number of persons enslaved and held on the continent expanded as slave exports declined, but the number was held within a maximum set by the peak decade of slave exports. That is, it assumes that the peak decade of captive exports set a level of total enslavement that was maintained from that decade until enslavement was halted; it is assumed that enslavement was halted suddenly at the start of a decade.

More steps are required before these estimates of continental enslavement can complete the decennial projections of African population. Variant 2 yields crude numbers of captives: it is necessary to apply assumptions on the age and sex distribution of those captives. Then it is necessary to enter the resulting age- and six-specific estimates of continental captives into the simulation, so as to account for their mortality. Finally, the simulation must be run multiple times to ensure that the various inputs and outputs are consistent for each region and for each decade. The application of Variant 2 will suggest that the total level of African enslavement remained virtually unchanged until the 1890s. As a result, this variant will suggest that the negative impact of enslavement—combining overseas and continental—was as much as twice what it is calculated in Variant 1.

Variant 3 assumes that the expanded number of persons enslaved during the nineteenth century on the continent was largely independent of the level of export slave trade. In accord with the impression given in the qualitative literature, the assumed rates of capture in Variant 3 tend to get higher as the nineteenth century proceeded. To illustrate this variant, Table 9.6 begins with estimated 1890 populations for each region. It then assumes that 0.5% of the population is enslaved each year, yielding the number of captives in the left-hand column. Other assumptions included in the table are that 90% of captives are retained, that mortality among those captives was 10% in the first year, plus an additional 4% seasoning mortality in the second year. It is assumed that 10% of the captives are sent to other regions, but it is also assumed that an equal number of captives is sent into the region from adjoining regions; this in-migrant population must bear a 4% seasoning mortality. This version of the model assumes, on a region-by-region basis, what is necessarily true for continental enslavement overall: that captive migrants from region to region cancel out in the aggregate. The difference, however, is that the continental migrants suffer the additional mortality of migration. Given the parameters adopted in Table 9.6, the results show that for annual slave exports of 44,800 (column viii), the total continental losses were 109,000, or a ratio of 2.5:1. In practice, to implement Variant 3 requires calculating an equivalent spread sheet for each decade of the nineteenth century, and then linking them.

Table 9.6. Estimates for the 1890s under Variant 3.

1890s

Region	i	ii	iii	iv	v	vi	vii	viii		
	# ensl captives	captives retained	ensl mortality	retained season mort	captive out-migr region	captive in-migr	in-migr season mort	captive out-migr Sub-S	Pop 1890	Captive Loss
Senegambia	11685	10516.5	1052	379	1169	1169	47		2,337,000	-1477
Upper Guinea	19400	17460	1746	629	1940	1940	78		3,880,000	-2452
Grain Coast	25500	22950	2295	826	2550	2550	102		5,100,000	-3223
Bight of Benin	22500	20250	2025	729	2250	2250	90		4,500,000	-2844
Bight of Biafra	30500	27450	2745	988	3050	3050	122		6,100,000	-3855
C. Sudan	77350	69615	6962	2506	7735	7735	309	6000	15,470,000	-15777
W. Sudan	28250	25425	2543	915	2825	2825	113	1500	5,650,000	-5071
Chad	11050	9945	995	358	1105	1105	44		2,210,000	-1397
Loango	41500	37350	3735	1345	4150	4150	166		8,300,000	-5246
Angola	21500	19350	1935	697	2150	2150	86		4,300,000	-2718
Horn	70000	63000	6300	2268	7000	7000	280	4800	14,000,000	-13648
E. Sudan	30000	27000	2700	972	3000	3000	120	2500	6,000,000	-6292
Mozambique	28650	25785	2579	928	2865	2865	115	15000	5,730,000	-18621
Tanganyika	48500	43650	4365	1571	4850	4850	194	15000	9,700,000	-21130
Kenya	44300	39870	3987	1435	4430	4430	177		8,860,000	-5600
	510685	459616.5	45962	16546	51069	51069	2043	44800	102,137,000	-109,351

Table 9.7 provides an indication of the estimates of Variant 3 for the full nineteenth century. It shows, in column 5, the number of persons enslaved and retained in sub-Saharan Africa according to the assumptions of Variant 3. The total number of persons enslaved each decade is the sum of Columns 2 and 5. Column 6 shows the total deaths occurring each year among those enslaved and held within the continent. The sum of Column 2 and Column 6, therefore, reflects the total number of persons removed from sub-Saharan Africa in each decade – either by migration or by death. According to Variant 3, by the mid-nineteenth century the annual loss of African population due to enslavement was roughly twice what it had been in the late eighteenth century.

Table 9.7. Decennial Enslavement under Variants 1, 2, and 3

Col. 1. Decade	Col. 2.	Col. 3. Variant 1	Col. 4. Variant 2	Col. 5. Variant 3	Col. 6. Variant 3
	Export losses	Continent enslaved	Continent enslaved	Continent enslaved	Continent losses
1890s	20,500	20,500	193,246	710,700	62,816
1880s	39,700	39,700	298,142	1,163,860	100,519
1870s	43,911	43,911	294,492	1,259,326	112,341
1860s	54,269	54,269	271,210	1,082,260	97,415
1850s	67,105	67,105	270,964	1,282,582	114,082
1840s	78,843	78,843	254,657	1,115,322	100,166
1830s	108,831	108,831	223,332	1,101,765	99,038
1820s	120,748	120,748	184,404	864,783	75,635
1810s	99,396	99,396	143,725	633,558	56,397
1800s	91,988	91,988	99,217	673,127	59,690
1790s	84,301	84,301		655,835	58,251

Further evaluation of Variant 2 and Variant 3 will involve comparing the losses under each variant with the losses calculated with the basic simulation, to provide estimates of the additional domestic cost of expanded enslavement for African markets during the nineteenth century.

Error Margins

Standard error figures for the Bayesian estimates of transatlantic slave trade are remarkably tight. (Examples)

Error estimates for export slave trades to Africa's north and east are far more difficult to estimate. Similarly, error estimates for the size and impact of the continental slave trade require greater conceptualization before they can be estimated systematically.

Conclusion

All of these quantitative estimates work within the framework of the estimates of population prepared and discussed elsewhere in this book – on a decennial level for 66 African regions – using estimates of birth and death rates and flows of captives sent out from Africa. For transatlantic slave trade, the Bayesian estimates provide a systematic, statistical estimate of missing data, and thus convey estimates with clear indications of their error margins. For estimates of slave exports to the north and east of sub-Saharan Africa, and for estimates of continental enslavement, the error margins are much more difficult to tie down. Nevertheless, the combination and interaction of the various estimates provides an improved vision of how African population changed over time in the course of the continuing and expanding experience of enslavement. In Variant 1 the number of continental captives is calculated as a side-effect of the number of captives exported from Africa. In Variant 2, the number of continental captives, by region, is based on the difference between the number of overseas exports in a given decade and the number of exports in the peak-export decade. In Variant 3, the number of continental exports is based on the projected decennial capture rate. These three types of calculations will yield three levels of estimates of enslavement-related migration and mortality within African regions, and will also yield revised population estimates for African regions and for the continent as a whole. In general results of the analysis show that—particularly for Eastern Africa and West Central Africa, but also for the West African savanna—enslavement brought serious displacement of populations and declines in regional population for the last half of the nineteenth century, so that only at the end of the nineteenth century did the continental population decline to the level of 140 million, from which it began to increase gradually at the start of the twentieth century.

Chapter 10

African Population & Migration: Projections, 1890-1950

Data and assumptions: continental conditions
Data and assumptions on local conditions
Growth rates revised for local conditions
High and low population projections, 1890-1960
Conclusion: Issues in the Demography of Colonial Africa

This chapter assembles data and models from previous chapters to propose African national and regional population figures by decade, 1890-1950, combining them with United Nations figures for 1950-2000 to yield a full set of population estimates for the twentieth century. The chapter concludes with a discussion of the colonial era in African population history.

Data and Assumptions: continental conditions

We have chosen to identify base populations for 1950 and 1960, thus including the growth rate linking them, on the argument that this provides the most robust statement of each base population. We have based our estimates first on U.N. estimates of 2006.[133] (For Ghana and Nigeria, where analyses of the 1950s were exceptionally strong, one may still ask whether the current UN estimates are improvements over the initial figures.[134]) While both 1950 and 1960 are treated as base years, in practice the 1950 population estimate for each territory is used as the basis for projection of earlier populations.

These qualitative and quantitative data, in association with demographic assumptions, are now to support estimates of net population growth rates for African territories from 1960 back to

[133] United Nations, *World Population Prospects*. We have relied upon the 2006 estimates of territorial population for 1950 and 1960. The Tabuthin-Schoumaker survey of sub-Saharan Africa relied on the 2002 estimates, and the same authors in surveying North Africa and the Middle East relied on the 2004 estimates. We have accepted the argument that the 2006 estimates, which differ in various details from the earlier series, are to be preferred. We are thankful to Sabine Henning of the United Nations Population Division for generously providing a set of total African national populations for 1950 and 1960 as estimated in 2002, 2004, and 2006.

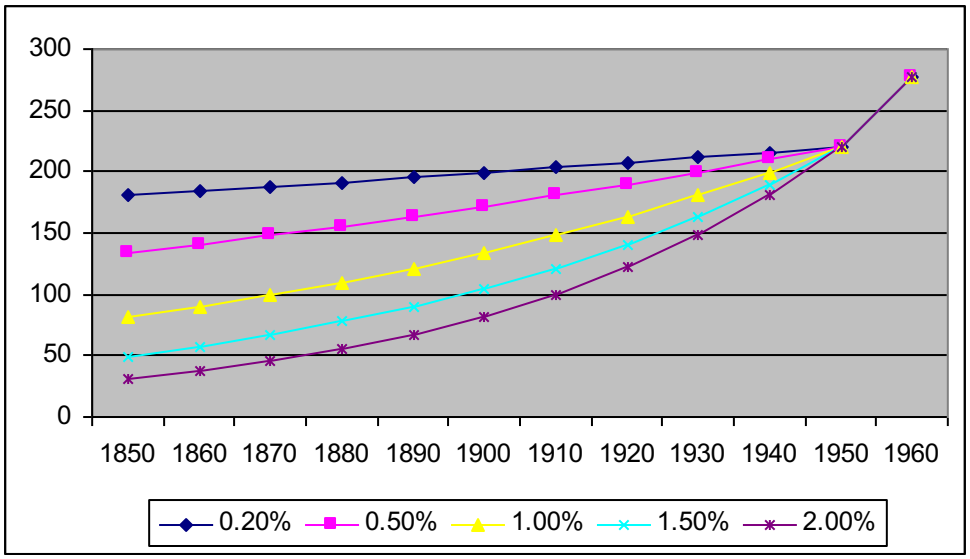
[134] We refer to the Okonjo estimate of 1962 population of Nigeria, and on the Ghana census of 1960.(Okonjo1968, Gil 1964) Other countries for which discrepancies arose between 1967 UNECA figures and later U.N. figures are Guiné-Bissau, Central African Republic, Gabon, Congo-Brazzaville, and Mozambique: in these cases we relied on the later U.N. figures. Growth rates in the 1950s appear generally to have been higher in East Africa and North Africa than in West Africa. Our thanks to J. C. Caldwell for advice on these points.

1850. To convey a sense of the outside limits of such speculation, Figure 3 displays estimates of population growth at low, medium, and high rates. The figure begins (at right) with a 1960 population of 278 million and a 1950 population of 220 million, and projects it back to 1850 at constant annual rates from a low of 2 per thousand (0.2%) to a high of 20 per thousand (2%).

Table 10.1. Estimated African Population by Geographic Region, 1950 and 1960. Source: Table B1.[135]

	Population 1950	Population 1960	Annual growth 1950-1960	
			Per thousand	percent
North Africa	44,113,000	56,869,000	26	2.6
West Africa	63,983,000	80,067,000	22	2.2
Central Africa	26,044,000	32,109,000	21	2.1
East Africa	39,355,595	50,367,595	25	2.5
Northeast Africa	31,091,000	38,709,000	22	2.2
Southern Africa	15,676,877	20,813,022	29	2.9
Subsaharan Africa	176,150,472	222,065,627	23	2.3
Africa	220,263,472	277,934,627	24	2.4

Figure 10.1. Constant Growth Rates, 1950 back to 1850.



It shows that, at 0.2% annual growth, a 1950 population of 220 million corresponds to an 1850 population of 180 million, while at 2.0% annual growth, the same 1950 population corresponds

[135] Continental estimates of population for 1950 and 1960 in this table are higher by about three million persons than the estimates in later tables. The difference is that persons designated as "European" and "Asian," mostly in Southern Africa, were eliminated from the 1950-1960 populations used for projection to earlier periods, since the ultimate purpose is to estimate populations that were at rise of enslavement in earlier times.

to an 1850 population of just over 30 million. Clearly, the reality we seek lies somewhere between these extremes.[136]

After evaluation of the data and alternative assumptions summarized in Step 3, we have chosen to project preliminary or "base-level" decennial growth rates for Africa as a whole, ranging from a low of 0.2% per year for the 1850s to a high of 1.5% per year for the 1940s. These are estimates of average or expected crude growth rates, not accounting for export slave trade. My overall assumption is that death rates declined at an accelerating rate from the mid-nineteenth to the mid-twentieth century, while birth rates remained relatively constant, so that net rates of population growth increased over time throughout the continent.[137] For the 1910s and 1930s, we assumed slight declines in growth rates from preceding decades because of war, economic depression, and fertility decline, in parallel with apparent declines in India. we assumed growth rates of no more than 0.2% in the mid-nineteenth century because the high insecurity of that era.

Table 10.1. Africa: Base-level Growth Rates

Decade	Annual growth rate	
	per thousand	percent
1951-60	24	2.4
1941-50	15	1.5
1931-40	8	0.8
1921-30	10	1.0
1911-20	2	0.2
1901-10	3	0.3
1891-1900	3	0.3

Figure 4 shows these base-level growth rates, and also shows the tolerance that would result from adding and subtracting a growth rate of 0.1% cumulatively, each decade.[138] This initial projection shows low and high continental African populations of 119 and 149 million, respectively, for 1850 as compared with 220 million for 1950 and 278 million for 1960. The resulting mid-level estimates for African population—149 million in 1850 and 155 million in 1900—are significantly higher than the received estimates of Willcox, Carr-Saunders, Biraben, and others. (Willcox 1931, Carr-Saunders 1934, Biraben 2003) The assumption of relatively low growth rates for the nineteenth century leads logically to these higher estimates of African population size in the nineteenth century and, indeed, in earlier times. (As we will see, further specification of regional growth rates yields still higher estimates of African population.) One

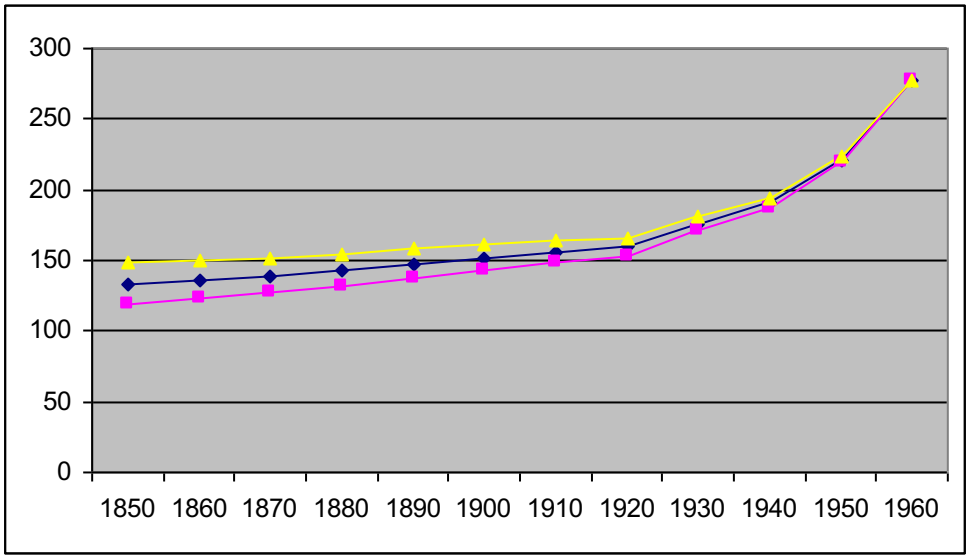
[136] In the second and third iterations of these population estimates, we began with base populations taken from 1931 colonial estimates, and projected them back at rates of 0.5 % and 1.0 %. See note 29 above.

[137] The overall pattern of "demographic transition," in which populations worldwide have changed, over the past two centuries, from high rates of mortality and fertility to low rates of mortality and fertility (with mortality declining first) is now known to have been far more variable than was earlier thought. Nonetheless, while the exact pace of historical change in African societies is not yet known, we argue that it is appropriate to retain the maintain the general assumption of demographic transition for Africa.

[138] The tolerances are cumulated: that is, the tolerance is plus or minus 0.1 % for the 1940s, 0.2 % for the 1930s, and 1.0 % for the 1850s.

implication is that, since these population estimates are higher than previous estimates, the negative impact of slave trade on these populations will tend to be estimated as less severe than in my previous estimates.(Manning 1990, pp. 60-85, 179-181)

Figure 10.2. Projected Continental African Population at Base-level Growth Rates, Showing Tolerances



Data and Assumptions on Local Conditions

We turn now to the issue of regional variations in growth rates according to any specific circumstances that can be identified. Before attempting detailed analysis of the available data, we propose a list of social circumstances for which one can project increases or decreases in population growth rates. Table 8 lists the eight situations we propose, along with estimates of the magnitude of the annual effect of each situation on population growth.[139]

Table 10.2. Situational Modification to Growth Rate

Type of Modification	Maximum Annual Magnitude	
	per thousand	Percent
a. Slave-trade disorder	-2	-0.2
b. Sub-Saharan slave exchanges	+ or - 3	+ or -0.3
c. Sub-Saharan slave exports	-6	-0.6
d. Post-slave-trade recovery	+4	+0.4
e. Colonial disorder	-4	-0.4
f. Income growth	+2	+0.2
g. Migration of free people	+ or -6	+ or -0.6

[139] Details of these estimates are available from the author; they are still subject to significant revision. The rubric for these estimates, appears to be satisfactory in its present form.

h. Epidemic and famine	-5	-0.5

The first three situations or categories of modification account for the impact of slave trade. Enslavement and its demographic impact are known to have been at a high level for many African regions in the nineteenth century. While the export slave trade across the Atlantic ended in the 1850s, exports across the Indian Ocean continued into the 1890s and exports to the Sahara and North Africa continued to 1900. The retention of captives within sub-Saharan Africa, long a by-product of slave exports, grew as a proportion of total enslavement and continued in some regions well past 1900. The flows of captives included those from the West African savanna to Saharan oases, the enslavement of people from the periphery of the great West African states of Sokoto and Samori, and the settlement of slaves along the routes from the Upper Congo and Lake Malawi to the Swahili coast. The task of assessing these regional flows and the overall magnitude of this nineteenth-century forced migration is intractable, and few serious efforts have been made at quantifying it.(Inikori 1980b, Manning 1981, Lovejoy 1989) For instance, up through the eighteenth century, the number of slaves exported from Africa may serve as an adequate index of the overall volume of African enslavement, but this approximation is no longer satisfactory for the nineteenth century.(Manning 1990, pp. 50-53)[140] The regions with the greatest slave exports after 1850 were Mozambique, Tanzania, the Horn, the Eastern Sudan, and the Central Sudan. In earlier estimates, we concluded that populations declined significantly as a result of slave exports as late as the 1880s in Mozambique and Tanzania, and that growth rates were slowed significantly for the remaining slave-exporting areas in the last half of the nineteenth century.(Manning 1990, pp. 79-82)

The remaining five regional variations in growth rate were important especially for the twentieth century. The end of slave trade commonly coincided with the colonial conquest, at times ranging from the 1870s to after 1900: see Table B4 for the timing of colonial conquest and the end of slave trade in each territory. Once slave trade ended, the return in security is presumed to have led not only to a decline in death rate but an increase in birth rate. This *post-slave-trade recovery* enabled growth rates to rise from base-level levels by an estimated 0.4% per year for one or two decades.

But colonial regimes, while they brought an imperial peace, also brought their own disorder. Especially for French and perhaps Belgian Central Africa, colonial regimes brought population decline, especially through fertility decline, especially as a result of disease spread in particular by African and European colonial officials. For this type of situation, we project that *colonial disorder* brought reductions in growth rates by as much as 0.3% per year, for periods from a decade to as much as 30 years. For other colonies, such as West African coastal colonies, *income growth*, especially through expansion of agricultural exports, brought higher fertility, adding to base-level rates by up to 0.2% per year for as long as the boom lasted.

[140] For the years before 1800, we have assumed that the number of captives retained in sub-Saharan Africa, for each region, was a constant proportion of those exported. After 1850 (and arguably earlier), the proportion of captives retained in Africa rose substantially and there is no obvious basis for estimating their numbers.

Epidemic and famine, finally, could have impacts that brought high mortality, reducing population growth rates by as much as 0.5% per year, but usually for no more than one to three years at a time.[141]

Having established a typology of varying modifications to the prevailing rates of population growth for each time period, the next step is to apply it and categorize each African region according to the situation it faced in each period. Table 10 provides a qualitative summary of the modifications we have made, for each territory and each decade, to the base-level growth rates displayed in Table 7. In cases where a cell is left blank, it is assumed that the base-level growth rate for that period is applicable to the region. Quantitative details of these modifications are shown in Table B3 of the appendix, which displays the categories and magnitudes of growth-rate modifications that we estimated for each decade, by territory. These estimates, while preliminary and speculative, are at least explicitly identified, to encourage updating based on more thorough evaluation of the descriptive literature for each territory.

Table 10.3. Outline of Modifications to Growth Rate

Source:

Region	1900s-20s	1930s-50s
North Africa	g) free immigration	
West African savanna	d) post-slaving recovery e) colonial disorder g) free out-migration	g) free out-migration
West African coast	f) income growth g) free immigration	f) income growth g) free immigration
Central Africa	e) colonial disorder h) epidemic	
Northeast Africa	d) post-slaving recovery e) colonial disorder h) epidemic	
East Africa	d) post-slaving recovery e) colonial disorder h) epidemic	f) income growth
Southern Africa	f) income growth g) free immigration	g) free immigration

Growth Rates Revised for Local Conditions

Summarizing the estimates of Step 5 makes it possible to estimate growth rates and then populations, for each territory and sub-territorial region, working decade by decade from the 1940s back to the 1850s. That is, for each region within each decade, we locate and summarize the modifications to growth rate because of local conditions and slave exports (from step 5). This process yields a revised growth rate for each decade, and a revised population for the beginning of each decade. Table 11 illustrates the range in regional growth rates calculated as a result of

[141] Examples included the influenza pandemic of 1918, cholera epidemics of the late nineteenth century in Eastern Africa, and sleeping sickness in Central and Eastern Africa in the early twentieth century..

this process for each of the slave-trade regions and for four of the ten decades under consideration.[142]

Table 10.4. Low and High Growth Rates (per thousand) for Selected Territories[143]

	1900-10		1930-40	
	high	low	high	low
Base-level Growth	**3**	**2**	**15**	**8**
Senegambia	5	2	15	8
Upper Guinea	4	2	15	8
Ivory Coast	2	0	15	8
Gold Coast	5	2	15	8
Bight of Benin	7	1	15	8
Bight of Biafra	4	1	15	6
Forest	1	0	13	6
Loango	3	0	15	6
Angola	3	1	15	8
Mozambique	3	2	15	8
Madagascar	7	4	15	8
Tanzania	7	2	15	8
Kenya	4	2	15	8
Horn	7	2	15	8
Eastern Sudan	7	6	15	8
Chad	7	2	13	6
Central Sudan	7	2	15	7
Western Sudan	7	4	13	6

High and Low Population Projections, 1890-1960

Results of previous sections are computed for each territory, and then are tabulated for geographic and slave-trade regions. While the detailed analysis and revision of growth rates is best conducted at the localized level of the colony or sub-colony, one can also learn from review and critique of aggregate results of the estimations. High and low estimates resulting from Table 11 have been tallied to provide summaries, for selected decades, for the geographical regions and slave-trade regions of the continent. Figures in Table 12 are for total populations in each geographic region; their totals are therefore estimates of the continental African population.

[142] Note that he variance in these growth rates reflects the difference in territorial growth rates under specific influences; the assumed margin of error for overall estimates (discussed in Appendix A) is in addition to these variations.

[143] Source: Table B5

Table 10.5. Low, Mid, and High Estimates of Regional Populations, 1850-1950[144]

	1900	1950*
North Africa	26,899,507 30,317,454 34,282,726	44,113,000
West Africa	39,226,230 42,250,843 45,739,035	63,983,000
Central Africa	17,400,469 19,011,066 20,881,463	26,044,000
East Africa	24,475,399 26,293,295 28,242,808	39,355,595
Northeast Africa	17,631,696 20,029,659 22,942,216	31,091,000
Southern Africa	9,184,663 10,677,171 12,471,520	15,676,877
Subsaharan Africa	113,463,269 118,516,888 123,882,654	176,150,472
Africa	142,674,350 148,846,515 155,489,422	220,263,472

* The United Nations low, mid, and high level estimates are identical for 1950.

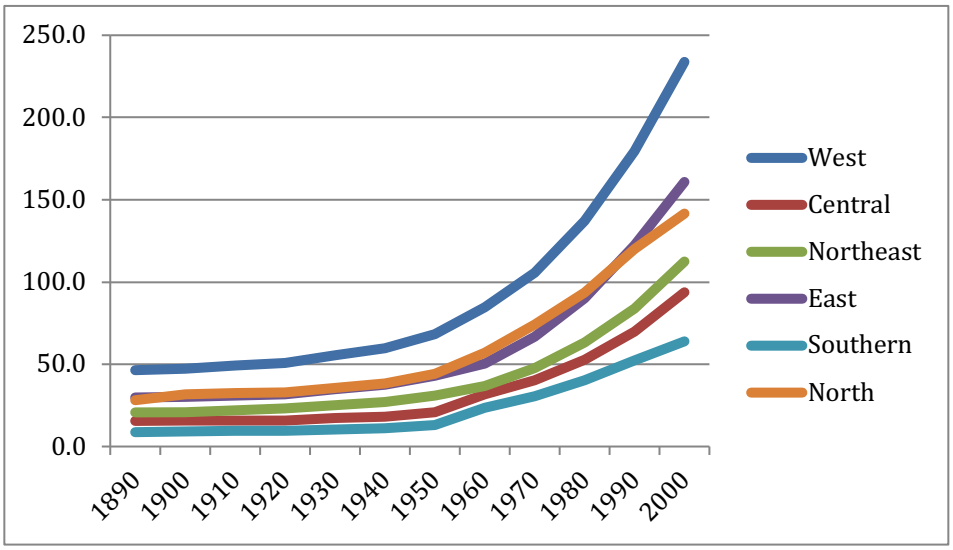


Figure 10.3. African population by region, 1890 – 1950.

[144] Source: Table B5.

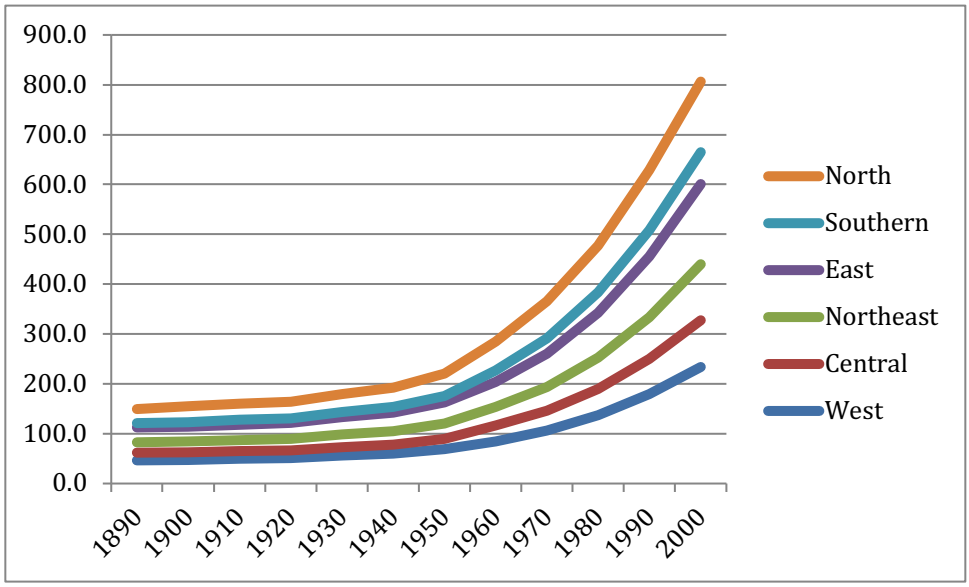


Figure 10.4. African Population, Regional and Total, 1890-2000.

Conclusion: Issues in the Demography of Colonial Africa

Linking national-era populations to colonial-era population estimates raises big questions about the colonial-era figures. We end up proposing a mid-level estimated continental population of 140 million as of 1890, which is almost exactly half of the 278 million estimated continental population for 1960. On the one hand the 140 million seems unexpectedly high, well above the received guesses of Carr-Saunders et al., and given that the continent had undergone two centuries of fairly intensive slave trade. On the other hand, all the qualitative indications are that official counts were systematically too low, and this same reasoning should apply to the almost completely uninformed global estimates of African population from earlier times. These new estimates may be modified significantly once they have been scrutinized with care, but we think it is unlikely that the previous continental estimates for the era 1890-1950 can be sustained. The substantial underestimation by colonial-era administrators and demographers was partly a result of their limited skills and resources. But their undercount also resulted from widely shared European views of African backwardness.

Regardless of which population estimates one adopts, the era beginning in 1890 was unquestionably an era of massive demographic transformation. Africans in this period experienced dramatic changes in vital rates, accelerating rates of growth, sharp changes in migration patterns, and the beginnings of spectacular urbanization. African expectations of life—though low in comparison with other regions and perhaps changing with a lag—nonetheless lengthened impressively. For the late nineteenth century, expectations of life at birth are estimated in the range of 20-25 years; expectations of life had risen to 35 years by 1950.(Caldwell 1985, Tabutin and Shoumaker 2000, United Nations 2004)[145]

[145] For studies of demographic history in Africa in precolonial settings, see Curtin 1989 and Diop-Maes 1996.

Similarly, African populations went from crude growth rates of no more than 0.2% to rates averaging over 2.0%. Of course, there was almost equally massive demographic change, far better documented, for Africa from 1950 to the present. By 1990 the expectation of life at birth was commonly over 50 years. (The subsequent HIV/AIDS epidemic, however, has reduced expectations of life in several countries back to levels of the 1960s—a devastating reversal.) These lessons of demographic change in the national era can be used as models to study the colonial era.

These dramatic demographic changes are known only in vague and inconsistent detail. When and how did the crucial transformations take place? At local levels, observers have argued that fertility rates rose in the twentieth century, though demographers tend to assume that the rise was in infant survival rather than fertility. But even if population growth came more from decreased mortality rather than increased fertility, what was the age profile of the declining mortality? How do increased African growth rates compare to those from other world regions? we hope that further efforts to identify territorially specific rates of crude population growth rates, along the lines of this exploration, may do much to indicate whether estimates of sufficient precision can be developed to yield answers on these questions. While there exist dispersed censuses and other enumerations for African populations for the nineteenth century and before, they are not set in clear context.[146] Demographic data are scattered (as with so many records on Africa) in documents created and held by a welter of individuals, agencies, and governments, in many languages and with inconsistent terms of reference. Records of European governments become more numerous from the late nineteenth century, but are focused on tax collection rather than systematic demographic concern. Even as censuses became more thorough in the 1960s, they were less than exhaustive, and in any case they documented populations that had changed greatly in structure from earlier times. It seems clear that colonial population figures for c.1900 were serious under-estimates and, therefore, that growth rates from that time to the 1960s were overestimated in the same measure.

Understanding the causes of Africa's pervasive demographic change is of great importance for learning about the African past and also for historical demography in general. The possible causes of demographic change include changes in nutrition, the rise and fall of social violence, epidemics, changing immunities, the nature and effectiveness of government, public health practices, changes in the nature and availability of traditional and modern medicine, and the connections brought by commerce and communication. The commonly offered explanations for demographic transition extend only with difficulty to colonial Africa, so that further analysis of African population change may be relevant for other regions. Modern medical and public-health practices, while valuable where applied, were simply not applied in sufficient degree to have brought the reductions in death rates that took place in Africa before 1940. Anti-malarial campaigns beginning in the 1940s—spraying of DDT along with the dissemination of chloroquine and antibiotics—brought rapid declines in mortality, but these changes do not explain the earlier declines in mortality. These new measures were applied unevenly across the continent, so that DDT seems to have been most effectively used in Southern Africa while chloroquine was more important for malaria reduction in East Africa.[147] Other

[146] For discussion of census data on Angola, see Thornton 1982, Curto and Gervais 2001, and McDaniel 1994.
[147] Gregory H. Maddox, personal communication.

possible causes of demographic change include natural transformations in the epidemiological atmosphere (that is, diseases may have become less virulent), social changes resulting from the end of large-scale enslavement, improved nutrition resulting from declining oppression and expanding markets, and perhaps development of new African healing practices.

Populations grew at modest rates in early twentieth century (though with some cases of negative growth). By the 1940s especially, population grew at an accelerating rate. From 1960 growth was consistently at rates above 2% per annum, and slowed only modestly at the end of the century.

Chapter 11

African Population and Migration: Projections, 1650-1890

1790-1890: Free, slave, and slave-descended populations of Africa
1650-1790: Free, slave, and slave-descended populations of Africa
North African slave-descended populations, 1790-1890.
1700-1800: African populations, slave and free
Indian Ocean African-descended populations
New World African-descended populations
Rising rates of enslavement in nineteenth-century Africa
Empirical results and discussion
Comparison with previous estimates
Methods of analysis
Conclusion

We now project population totals [with age and sex distribution, hopefully] for each decade from the 1890s back to the 1650s. We work from a combination of 1890 populations (chapter 10), numbers of slave exports (chapter 9), estimates of continental slave trade (chapter 6), and estimates of age and sex composition and mortality/fertility rates of each slave flow (chapters 4, 5, 6, 8). In this chapter we tabulate the results by region and summarize the results.

African Population, 1650 - 1890

The period from 1790 to 1890 is that in which our estimates are most complex. We begin by linking our back-projections to regional population estimates for 1890. Then we project back according to three sets of assumptions. First, our demographic simulation calculates population reproduction and the effects of export slave trade on populations in regions from which slaves were taken. But in region after region of Africa, the export slave trade declined beginning some point in the nineteenth century. As a result, according to this assumption, the negative effect of slave exports on African population became progressively smaller as the nineteenth century proceeded. Our second assumption is that the level of enslavement remained unchanging even as the level of slave exports declined, so that the number of captives retained in African regions increased as slave exports declined. The results of this dual analysis, shown in Figure 3, indicate that African continental population declined moderately in the course of the century, especially in regions where enslavement was most serious.

Table 11.1. African Population Estimates, by Region and Decade, 1650 - 2000

Region	1650	1660	1670	1680	1690	1700	1710	1720	1730	1740	1750	1760	1770	1780	1790	1800	1810	1820
West	49.3	49.6	49.9	50.2	50.3	50.4	50.3	50.1	49.9	49.6	49.4	49.0	48.4	47.9	47.4	47.0	46.6	46.5
Central	20.0	20.2	20.4	20.6	20.7	20.8	20.9	21.0	20.9	20.6	20.3	20.1	19.8	19.5	19.2	18.7	18.3	17.6
Northeast	20.1	20.2	20.3	20.3	20.4	20.4	20.5	20.6	20.6	20.7	20.8	20.8	20.9	21.0	21.0	21.1	21.1	21.1
East	26.9	27.2	27.5	27.9	28.2	28.5	28.8	29.2	29.5	29.9	30.2	30.6	30.9	31.3	31.5	31.8	32.1	32.0
Southern	6.5	6.5	6.6	6.7	6.8	6.9	7.0	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0
North	19.0	19.4	19.8	20.2	20.6	21.0	21.4	21.8	22.2	22.6	23.0	23.4	23.8	24.1	24.5	24.9	25.3	25.7
Africa	141.7	143.1	144.5	145.8	147.0	148.0	148.9	149.7	150.2	150.6	150.9	151.3	151.3	151.4	151.3	151.3	151.3	151.0

Region	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
West	46.4	46.3	46.2	46.2	46.2	46.3	46.4	47.4	49.2	50.7	55.6	59.7	68.4	84.7	105.7	137.0	179.7	233.8
Central	16.9	16.5	16.1	15.9	15.8	15.7	15.6	15.7	16.0	15.9	17.2	18.2	20.7	31.9	40.5	52.6	70.0	93.8
Northeast	21.0	20.9	20.8	20.8	20.7	20.7	20.7	21.0	22.2	23.2	25.2	27.1	31.1	36.9	47.7	63.2	84.0	112.5
East	31.6	31.2	30.9	30.6	30.2	29.9	29.8	30.2	31.1	31.8	34.9	37.4	43.0	50.4	66.7	90.3	122.3	160.8
Southern	8.1	8.2	8.3	8.4	8.5	8.6	8.7	9.2	9.5	9.6	10.5	11.3	12.9	23.5	30.7	40.3	52.5	63.9
North	26.2	26.6	27.0	27.4	27.7	28.0	28.2	31.7	32.4	32.7	35.8	38.4	44.1	57.0	74.1	93.7	119.9	141.6
Africa	150.1	149.7	149.3	149.2	149.1	149.1	149.4	155.1	160.3	164.0	179.2	192.0	220.2	284.4	365.3	477.1	628.4	806.4

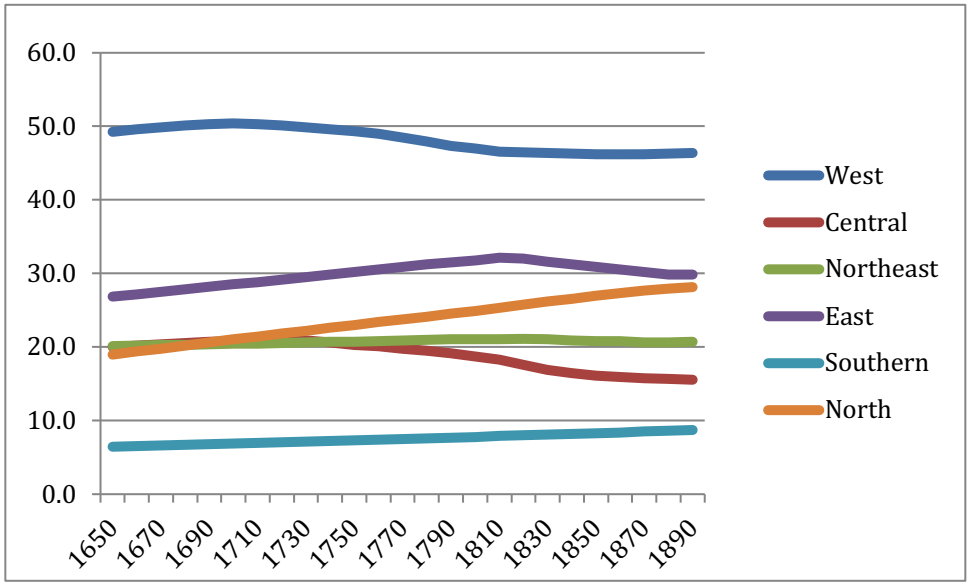


Figure 11.1. African regional populations, 1650 – 1890 (high enslavement level)

In addition, note low, middle, and high level for each method. Show the overlap and the preferred estimate out of the nine different estimates.

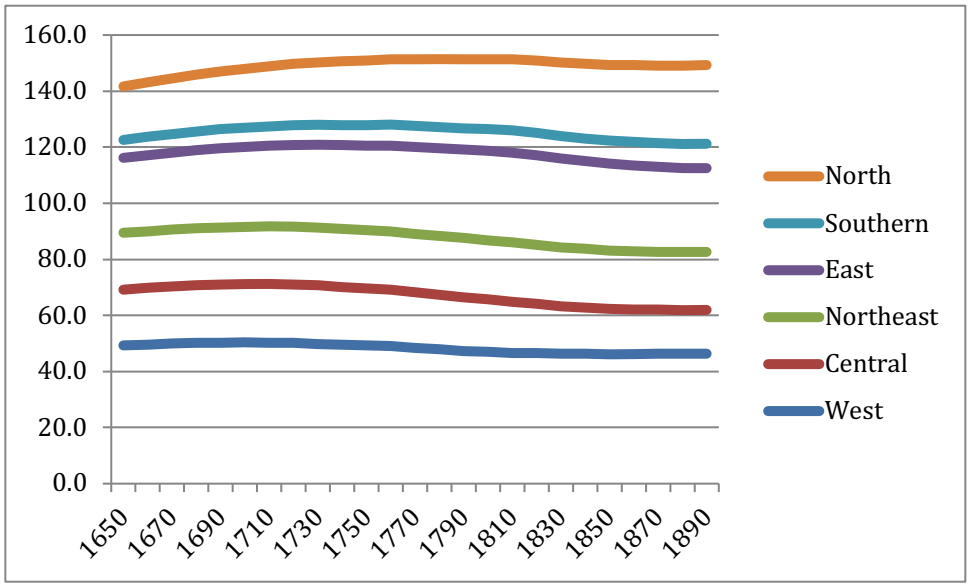


Figure 11.2. African population, total and regional, 1650 - 1890

Project back at high-growth rate (constant ratio of domestic enslavement), to 1650. For the period from 1650 to 1790, we have estimated populations using the simulation alone, so that the export of captives determined the deviations from normal rates of natural increase. The results of this analysis show that, especially for West and Central Africa, the steady expansion of slave exports caused increasingly serious population decline. Figure 11.4 shows a continental population

held almost constant at 140 million, while populations declined in West and Central Africa. Calculations have not yet been completed for the period 1650 - 1700, but it is expected that they will project a modest increase in population for almost every region in Africa during that time.

The contrasting impact of external slave trade on the western and eastern coasts of Africa stands out clearly in the data displayed in Table 11.1. For West Africa, the region reached a peak population of 50.4 million in 1700, then declined slowly to a regional low of 46.2 million in 1850, and began growing from 1880. For Central Africa, the region reached a peak population of 20.9 million in 1710, then declined at a somewhat more rapid rate to a low of 15.7 million in 1900, then began to grow. East African population declines came in the nineteenth century: Northeast Africa reached a peak of 21.1 million in 1800, then declined to a low of 20.7 million in 1870, and began to grow from 1900; East Africa reached a peak of 32.0 million in 180 and declined somewhat more rapidly to a low of 29.8 million in 1890, afterwhich growth rturned.

For the continent as a whole, it reached a peak of 151.4 million in 1780, then declined to a low of 149.1 million in 1870, and then began to grow. After 1900, continental population grew by 5 million in the first decade, rose to 15 million in the 1920s, to 64 million in the 1950s, and to 150 million in the 1980s. The rate of increase in population growth (the second derivative of population size) reached its peak in the 1940s and 1950s. Thus, the year 1950 may be seen as the best choice for the inflection point separating the earlier period of slow growth from the latter period of very rapid growth.

Summarizing the results of the above pieces of the analysis, Figure 11.3 shows continental African population from 1700 to 2000, presented on a logarithmic scale that gives more emphasis to the rate of population growth than to the absolute magnitude of population. It shows unchanging or negative growth until 1890, then accelerating growth until late in the twentieth century, and then decelerating growth. Figure 11.3 also shows the comparison of our results with a widely circulated set of previous estimates, in which Angus Maddison has estimated historical populations for Africa and for all other regions of the world.(Maddison 2001) As is clear, Maddison's figures assume smaller populations and higher rates of growth than ours.

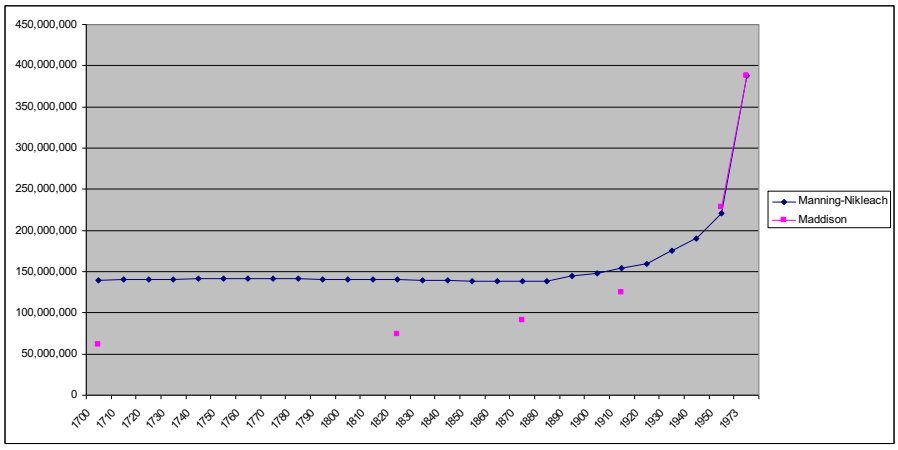


Figure 11.3. African population, 1700 – 2000: two sets of estimates. (Log scale?)

Using three related types of statistical analysis, we have been able to assign confidence intervals to our estimates of continental population, and to the constituent regional populations. Assuming the 1950 populations to be fully accurate, Figure 11.4 shows the 95% confidence interval surrounding our estimates of African continental population from 1940 back to 1700. We believe these confidence intervals are an important addition to the discussion of African population, and we describe the process of deriving them in a separate study.

Figure 11.4. African population, 1650 – 1950: 95% confidence intervals.

Rising rates of enslavement and captive retention in nineteenth-century Africa

The issue of the number of Africans held in slavery has been a vexed and indeterminate aspect of the large literature on slavery and slave trade. We have attempted to estimate the size and structure of African populations of slaves and their descendants, revising and expanding an analysis in Manning (1990). For each slave-trade region, we have identified the peak post-1780 decade in slave exports, calculated the number of captives seized in that decade, and have assumed that the number of captures per decade remained unchanged from that time through the 1880s. We subtract the number of slaves exported, and assume that the remained were held in slavery within the region. Figure 11.5 shows, for West Africa as a whole, the estimated free and slave populations (where "slave" populations includes those enslaved and their offspring, whether they remained in slavery or gained freedom).

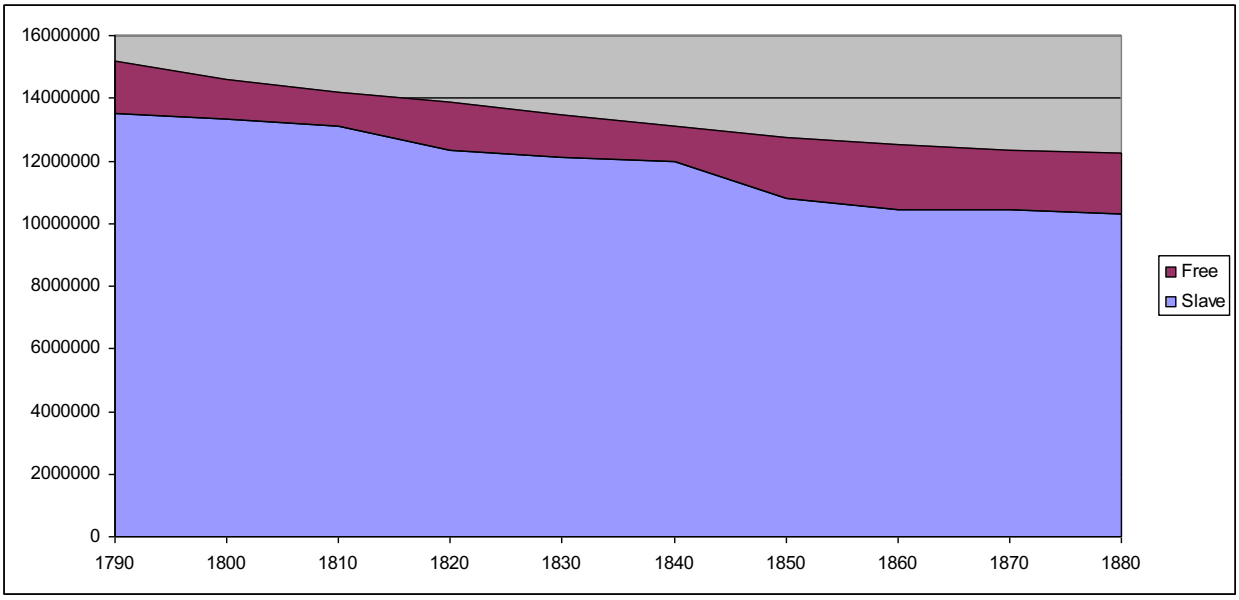


Figure 11.5. Free and slave populations of West Africa, 1790-1890.

The slave populations thus estimated, while large indeed, appear to be below the historical reality. The descriptions given in the qualitative historical literature, especially for the savanna regions, suggest that the enslaved may have been a majority of the total population, rather than the 30% suggested in Figure 11.5.(Meillassoux, Klein, Lovejoy, Miers & Roberts, etc.) While the estimates of our procedure are thus most probably very imprecise, an important

logical conclusion results from this analysis. That is, the only way the slave populations could become as large, at the end of the nineteenth century, as suggested in the historical literature, is if the rate of capture and enslavement rose dramatically during the course of the century. It is our belief, therefore, that the very large numbers of Africans in slavery were a phenomenon of the late nineteenth century and only of that time. Our quantitative analysis thus confirms the general impression given in the qualitative literature—that the number of persons held in slavery in Africa was relatively small in the seventeenth century, grew significantly during the eighteenth century, and grew to an extraordinary peak in the late nineteenth century.

Comparison with Previous Estimates

We retain the practice of identifying a base population for each territory at a given date and then projecting backward at high and low rates. But I have modified the procedure by identifying smaller and more specific regions within which to analyze population growth, and have moved to identifying base populations for 1950 and 1960, rather than 1931. In projecting populations back to 1850, I now attempt to estimate variations in growth rates for each decade, through greater detail in assumptions and review of available demographic data. Also review the sensitivity analysis in this study with that was published in 1980s.

New population estimates are higher. One implication is that, since these population estimates are higher than previous estimates, the negative impact of slave trade on these populations will tend to be estimated as less severe than in my previous estimates.(Manning 1990, pp. 60-85, 179-181)

The estimates of African populations as influenced by slavery and slave trade are a substantial revision and, we believe, improvement of the earlier estimates of one of us.(Manning 1990) The demographic simulation has been revised to follow demographic procedures more strictly, for instance by analyzing in five-year periods and allowing for both fertility and mortality in captive populations. The vital rates have been adjusted, especially by lowering assumed rates of natural increase to levels more appropriate for the tropical world of the seventeenth through nineteenth centuries. And the colonial-era populations from which we project back in town are now much larger than before, as a result of a more appropriate analysis of African populations between 1890 and 1950. The estimated volumes of overseas slave trade, however, are very much the same in the two analyses.

For the populations of West and Central Africa in the eighteenth and nineteenth centuries, Figure 11.6 shows the aggregate figures projected in this study as compared with those of Manning in 1990. We find it most interesting to see that the interpretive conclusion of the analysis—that regional populations declined in the era of large-scale overseas slave trade—are reaffirmed even though the total population size is now estimated at a higher level than before.

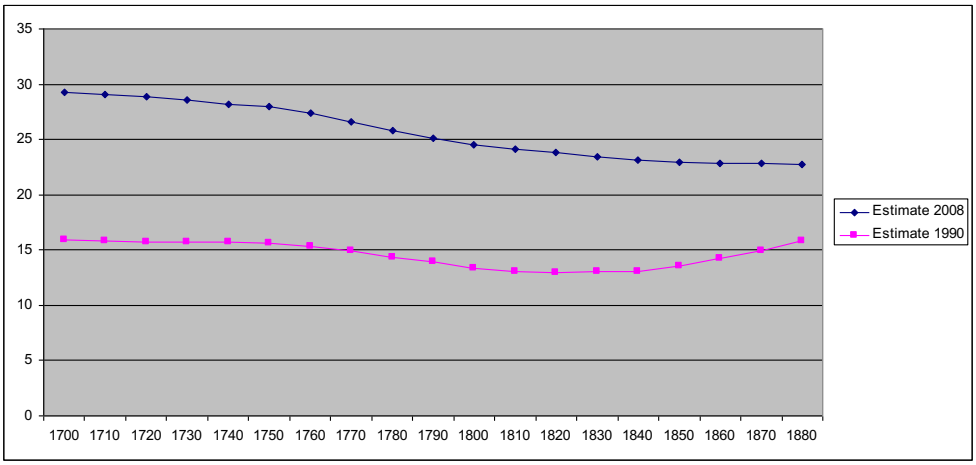


Figure 11.6. West and Central African populations, 1700 – 1890.

For the populations of East Africa, Figure 11.7 shows a parallel comparison of our new estimates with those of Manning in 1990. Similarly, the results show an East African population that grew until the early nineteenth century, when explosion of large-scale overseas slave trade brought a substantial decline in regional population. To summarize the comparison of the present analysis and the earlier analysis, there are three main differences. First, the overall population from which captives were drawn is now thought to have been much larger, based on what we have learned about twentieth-century population size. Second, the rate of natural increase is now thought to have been lower, based on comparison with growth rates in other parts of the tropical world. Third, the overall mortality of captives is now assumed to have been higher than thought—not because the individual rates of mortality were higher, but because we are now accounting for the mortality of the large number of people enslaved in nineteenth-century Africa.

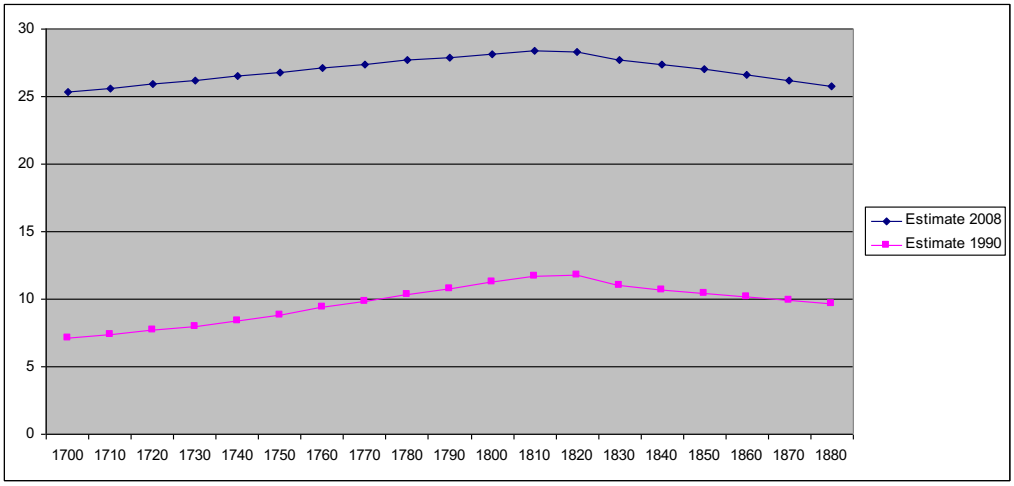


Figure 11.7. East African population, 1700 – 1890.

North African Slave Descended Populations, 1790 - 1890

This analysis, because it has been constructed in comprehensive terms in order to give consistent population estimates over more than three centuries, provides results on some other variables that will be developed as the work goes to full publication. First, the analysis yields estimates of the number of sub-Saharan Africans entering North Africa and the proportion of slave-descended persons in the overall North African population. Figure 11.8 shows North African populations from 1700 to 1890, distinguishing free from slave-descended populations.

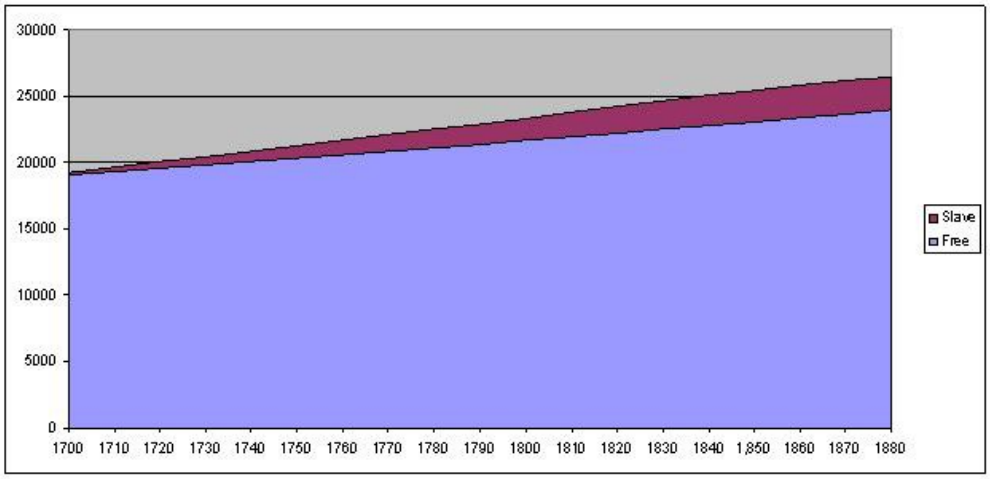


Figure 11.8. North African free and slave-descended populations, 1650-1890.

Similarly, the system of analysis allows for estimates of the disembarkations of captive Africans in each region of the Americas and for the Indian Ocean. Further, projecting the survival and progeny of these involuntary migrants can yield totals for the slave-descended population for each American region and the Americas as a whole. Overall these additional estimates, while limited in their precision, pro- vide additional elements of a global analysis, showing the relationship of these migrant-descended populations to the African populations from which they came.

Indian Ocean Slave Populations 1650-1890

Figure 11.9. Indian Ocean African-descended populations, 1650-1890.

New World Slave Populations, 1650 - 1850

Figure 11.10. New World African-descended populations, 1700-1890.

Review of Methods of Analysis

History backwards and forwards. The methodology that we are calling "history backwards and forwards" has involved developing our results through a structured alternation between working from present to past and then working from past to present. We think it may

have some more general implications for historical methodology, but here we focus on our own procedure.

First we project backwards, from recent known data to estimate previous data. For populations we work from one decennial point to the previous one, accounting for factors of growth and decline as we can for each of the periods between these points. Then we work forward, decade by decade, with the simulation of population and migration, checking to see if the population at the end point (the most recent date) corresponds to that with which we started. If necessary, we repeat the procedure until the estimates are consistent, going backward and forward. As a concluding step, we articulate a narrative of the changes as we understand them to have happened, moving forward in time.

A simple but important example of the benefits of using this procedure is that analysts of precolonial African populations had not paid attention to the recently improved and increased population figures for 1950 and thereafter. As a result, they failed to notice that they had implicitly assumed African growth rates that were unreasonably high, and that their estimates of precolonial (and also colonial) African populations were unreasonably low. So a basic lesson of "history backwards" is that one should ensure that descriptions for earlier times are not inconsistent with known data for later times. Similarly, a lesson of "history forwards" is that a historical narrative requires tracing the main steps moving forward in time, preferably with explanation of the reasons for change.

Vital rates. By vital rates we mean rates of birth, death, and migration. Birth and death rates are the most obvious and vital of vital rates, and the most commonly recorded. But migration is a fundamentally important human process, and our ability to trace migration and its implication has improved greatly with modern spread sheets. Studies of human population for the time to come require a special effort to combine all the different ways of analyzing birth, death, and migration.

For African populations, the work of John C. Caldwell has been especially important in reviewing historical and contemporary rates of birth and death. In particular, he has been central in showing how populations of colonial Africa were underestimated, in part through overestimation of birth rates and underestimation of death rates.(Caldwell and Schindlmayr 2002) John K. Thornton launched work on the analysis of documents on precolonial African rates of birth, death, and migration.(Thornton ??) While the work was pathbreaking in demonstrating the availability of documents and the relevance of such analysis, review and in some cases replication of his analyses by our group shows that his estimates of rates of natural increase and expectations of life at birth were too high, and the assumptions of our analysis have been revised accordingly. On rates of migration, our analysis requires estimated rates of enslavement and migration, but also provides ways to check the validity of those estimates. The analysis also confirms the importance of age-specific rates of migration.

Statistical methods. The analysis includes four categories of analysis, which combine to give explicit statements of the degree of precision in the results or confidence one may have in the results. First, for the estimates of African populations from 1890 to 1850, an analysis of the possible errors in estimated population growth rates yields confidence levels for those

populations.[148] Second, for the numerous types of populations and vital rates included as inputs in the simulation of slave trade, a sensitivity analysis shows the relative significance of the various input variables in changing simulation results. This sensitivity analysis demonstrates that the most significant input factor was the net rate of reproduction in African populations. Third is an analysis of the confidence level in population levels estimated for the period from 1700 to 1890. Fourth is an analysis of confidence levels in the numbers of captives embarked each decade from the various regions of the African coast.[149]

[148] Nikleach appendix
[149] Sharpnack and Liu.

Chapter 12

African Population, 1650-2000:

Comparisons and Implications of New Estimates

Plausibility of the New Estimates
Global Comparisons
African Implications
Africa in global context

Plausibility of the estimates

The principal reason that the new estimates differ from previous estimates is that they were constructed through a comprehensive analysis. Previous studies took a piecemeal approach, investigating restricted regions, short periods of time, or a limited range of social interactions. Addressing the fuller scope of issues permitted the location of contradictions, lacunae, and errors in analysis. The effort to address the full range of issues in African population history has resulted in an argument that is more internally consistent. The groundwork for this analysis was the research performed on African populations under the auspices of the United Nations. For 1950-2000, the current decennial estimates of African population published by the United Nations Population Office are broadly dependable, thanks to years of review and analysis by demographers at the UN and elsewhere. The population totals for 1950 and 1960 are well above those first reported in censuses and surveys at the moment of African national independence. Thus, the true size of the African population in recent decades has only gradually come to be recognized.

Documenting African population for the years before 1950 will require an approach analogous to that successfully applied to the post-1950 years: large-scale, collaborative work, piecing together the many available shreds of evidence into a coherent global pattern. The program of estimation reported on here is an initial stage in the comprehensive analysis of the African demographic past that needs to be pursued.

Meanwhile, the literatures on African history, economic history, and demographic history have generally been skeptical of the notion that Africa had a large and dense population from early modern times, skeptical of the notion that African rates of population growth were lower than those of other regions, and skeptical of the notion that enslavement caused decline in African population. Thus, arguing for the plausibility of the new estimates requires commentary on these existing threads of skepticism about the idea of a dense pre-slave-trade African population.

First, there is the skepticism based on a habitual reliance on colonial statistical records. During the years before World War II, it was widely assumed that the African continental population had risen from about 100 million in 1900 up to about 130 million in 1930. It has only recently been noted that, to reach from 130 million in 1930 to 220 million in 1950, Africa's population would have had to grow at 2.7% per year through depression and war. Global comparison shows that no large population worldwide was growing at such a rate before 1950—the growth rate must have been lower and the earlier populations must have been higher. That is, African populations of the early twentieth century turn out to have been significantly under-reported. Such under-reporting is understandable from the viewpoint of African communities. Presumably, African communities had little incentive to present themselves for enumeration when the main results of enumeration were taxation and recruitment rather than provision of social services. Only from the 1950s, once social services began to appear in the national era—and when political representation began to be determined by population size—did the response to population surveys grow more positive.

Figure 1. Estimates of African Population, 1500 – 2000.

A second basis for skepticism about large early-modern African populations came from the piecemeal approach of studies in demographic history. Perhaps understandably, scholarly studies from the 1960s through 1980s worked on short periods of time and portions of the African continent, so that they were never able to compare the figures they were using with continental figures. West Africanists studied the Atlantic trade; East Africanists, after a delay, studied the Indian Ocean trade; there did not yet exist a continental picture.[150] For the precolonial era, analysts have given insufficient attention to the difference between the nineteenth century, when enslavement raged over most of the African continent, and the previous centuries, when the Atlantic slave trade was the main engine of the patterns of migration and social disruption that affected West and Central Africa most severely.

A third basis for skepticism about the size of African populations and the effects of slave trade came from comparison with European migration. Since it was known that Europe, in the years after 1850, was able to grow in population even as large numbers of migrants left their home countries, it seemed to many observers that Africa ought also have been able to avoid population decline. After all, Africa's ten million emigrants compared to Europe's 50 million. Nonetheless, a detailed analysis shows that Africa's export slave trade was indeed sufficient to reduce the population of major regions and, for over a century, of the continent as a whole. The negative factors that made the difference were the high general levels of mortality for Africa, the additional mortality brought by the violence of much enslavement, the loss of young adult females and their offspring, and the high levels of maritime mortality in the days before steamships. For the reproduction of African population, the key group was fertile females, generally those in the age group from 15 to 45. As soon as enough of them died or were exported, the result would be sufficient to halt population growth.

A fourth basis for skepticism, questioning the negative impact of enslavement on African population, argued that African nutrition improved with the arrival of American crops (maize,

[150] My 1990 attempt at a continental picture fell short in at least two ways: it was not linked to post-1950 populations and it did not enable readers to verify its calculations.(Manning 1990a)

manioc, peanuts, etc.), and that African population therefore expanded. This argument is plausible, but has not yet come close to verification. That is, we have yet to verify when American crops became a significant portion of African diets, and have yet to verify that they were substantially more productive than the previous African crops.(Manning 1982, Wigboldus 1986)[151] It is possible, therefore, that Africans of the nineteenth century had a broader diet but consumed no more calories than their predecessors of the sixteenth century.

All of these are factors that are contained within the post-1450 period of Atlantic maritime voyages. An additional element of the overall African demographic debate is that of whether African population in earlier—"medieval"—times was dense or sparse. Sometimes it is argued that the coastal regions of West African and Central Africa had been extremely sparse in these times, and that they were settled from further inland only in early modern times. For instance, it has been argued that the prevalence of malaria and other tropical diseases prevented population from becoming dense. This time of argument lacks plausibility because the presence of infectious disease, while a negative factor in the short term, is a clear indication that a dense population has existed in a region over the long term, as such a population was necessary to sustain the disease. Language distribution is another key to the historical depth and density of population: for West Africa in particular, the distribution of subgroups of the Niger-Congo language group indicates that populations have lived and migrated—in both the forested and savanna zones—for thousands of years, with a time depth far greater than of populations in Europe. This does more to demonstrate that West African population was ancient than that it was dense, but it dismisses the notion that any regions of West Africa were unsettled.

Global Comparisons

The new estimates of African population, when compared with populations elsewhere in the world, are shown to be different indeed from previous estimates. Table 2 shows Africa in global context of the new estimates and previous estimates (as given by Maddison 2001). From 1700 to 1900, African population was roughly stagnant, while the populations of all other major world regions grew at accelerating rates: by 1900 African population had declined to no more than one tenth of the global total. African populations began growing in the twentieth century as growth rates slowed in some areas and accelerated in others. In the last half of the twentieth century, African populations grew at a very high rate, and by the time these growth rates began to decline, African population had again reached one seventh of the world total.

In addition to this planetary comparison of population totals, here are some addition comparisons of population size and density. Comparing Africa with Eurasia reveals a remarkable parallel in population density. Africa, in its surface area, has some 30 million square kilometers, while Eurasia has some 53 million square kilometers. Africa's current population is roughly one billion, while that of Eurasia is roughly four billion. Thus, Africa's population density is now just short of half that of Eurasia.[152] For 1700, Maddison shows Eurasian population at 530 million

[151] On maize, see Miracle 1996 and McCann 2005; the latter gives us nothing new on maize adoption. Similar work needs to be done worldwide.

[152] This comparison in continental areas can be adjusted by accounting for underpopulated areas—the Sahara in Africa; Arabia and Siberia in Eurasia—and the results tend to cancel out. Yet another version of the comparison is to

and African population at 60 million; the new estimates show an African population of 140 million in 1700. Thus, the new estimates show an African population density that was half that of Eurasia—thus, the same ratio as at present—while Maddison's figures propose an African population density in 1700 that was less than one fourth that of Eurasia. That is, the old estimates argue that Africa was consistently a sparsely populated continent until very recent times; the new estimates argue that Africa was not far behind Eurasia in density and has maintained its relative position in population density over the centuries.

Table 12.1. Maddison's Estimates (2001) of World Population [153]
(showing % of global population according to new and old estimates for Africa)

	1700	%1	%2	1820	%1	%2	1913	%1	%2	1950	%
Africa1	**140**	21		**140**	13		**145**	8		**228**	9
Africa2	61		10	74		7	123		6		
Asia	**402**	59	67	**710**	64	68	**978**	54	55	**1382**	55
L. Am	**12**	2	2	**21**	2	2	**81**	4	5	**166**	7
Europe	**125**	18	21	**224**	20	22	**497**	25	28	**572**	23
W. shoots	**2**	0	0	**11**	1	1	**111**	6	6	**176**	7

Comparing Africa and Europe reveals a remarkable parallel in population size over the long term and shows both parallels and contrasts in the history of migration. European and African populations are roughly equal today, but Europe's population density is three times that of Africa, since Europe (including Russia) is only 10 million square kilometers in area. The two regions had equal populations of some 140 million in 1700. Between those dates, however, European populations rose at a steady rate with African population remained stagnant until the mid-twentieth century. In migration, Europeans outnumbered Africans as out-migrants from 1500 to 1600, Africans outnumbered Europeans as migrants from 1600 to 1850, Europeans outnumbered Africans again until 1960, and African migrants became most numerous thereafter. Among other differences in the migratory patterns were that, in the era of slave trade, there were few slaves among European migrants, and European migrants were able to return home. In times after 1850, European migrants traveled on low-mortality steamships, while the ongoing African slave trade continued to exert a high toll in mortality. Some factors worked in the opposition direction. In monogamous Europe, the absence of males left women unmarried or marrying later in life, thus affecting their fertility. In polygynous Africa, the remaining women still had children

compare populations to areas of arable land for Africa and Eurasia—these too tend to show an African density about half that of Eurasia.

[153] Table 4 source: Maddison (2001) 175, 183. Maddison's "Western Offshoots" include the United States, Canada, Australia, and New Zealand; "Europe" includes the entire territory of the former Soviet Union. I calculated the growth rates shown.

in marriage or concubinage; indeed, it seems that the long-term shortage of males brought by slave trade expanded the frequency of polygyny (if not of formal marriage) in Africa.[154]

Africa and the Americas provide remarkable contrasts in population history. The Americas have 41 million square kilometers in area, but if one subtracts the 10 million square kilometers of Canada, the result is equal to the area of Africa. At present the populations and therefore the population densities of Africa and the Americas are roughly equal. In 1700, however, the Americas had only some 13 million inhabitants (at least two million of them of African descent), so that the population density of the Americas was one tenth that of Africa.[155] Among the variations in patterns of population were that American populations declined sharply because of disease in the sixteenth and early seventeenth centuries, from 1650 to 1850 African populations declined through slave trade as American populations rose through African immigration and recovery of the indigenous population, and American populations grew rapidly through European migration after 1850.[156]

African Implications

A.G. Hopkins, in his groundbreaking analysis of West African economic history, provided a broad description of "the domestic economy" in contrast to trans-oceanic and cross-desert trade.(Hopkins 1973) In these terms, total output or Gross Domestic Product of African economies is the sum of the output of the domestic economy and the net value of "international transactions" or trans-oceanic and cross-desert trade. In practice, analyses of the latter "international transactions" have remained the principal basis for large-scale economic analysis of Africa up to the present. But the new population figures suggest that the "domestic economy" was much larger than has been realized, and that the "international transactions" were a smaller proportion of GDP than previously realized. That is, the historical levels of African trade across the Atlantic are known, within an order of magnitude, from the fifteenth century to the present. Levels of African trade across the Sahara, the Red Sea, and the Indian Ocean are known to a vaguer extent. Now that we have new and higher estimates of African population, it is necessarily the case that estimates of output in the domestic economy for sub-Saharan Africa are larger than before, and that the ratio of intercontinental trade to GDP will appear smaller.[157]

For present purposes, therefore, the framework of the "domestic economy" seems vague, in that it avoids identifying the levels of exchange and economic interaction within the continent. Review of this issue requires a further typological breakdown, distinguishing self-sufficient production, local markets, cross-regional commerce within sub-Saharan Africa, and commerce

[154] The large-scale, steamship-borne migrations from 1850 to 1940 transported migrants from other densely populated regions (Europe, East Asia, South Asia) but not from Africa. Only by 2000, when Africa had again become relatively densely populated, did overseas African emigration again become significant. McKeown 2004.
[155] Or an American population density one fourth that of Africa, using Maddison's population estimate.
[156] In the sixteenth and seventeenth centuries, African populations too may have been limited by the global circulation of diseases in that era.
[157] For an earlier discussion on the balance of the domestic economy and overseas trade in the Bight of Benin, see the works of Peukert and Manning: for the kingdom of Dahomey, Peukert assumed export value reached only 4% of GDP; for the larger Bight of Benin, Manning assumed export value reached 10% of GDP. Manning proposed a three-century series on export revenue and per capita export revenue, with rougher estimates of GDP. Peukert 1978, Manning 1982.

with regions beyond sub-Saharan Africa. We need to know about each of these in contrast to but also in connection with overseas and cross-desert trade. Analysis so far has focused primarily on trans-oceanic commerce and has given us little detail on the continental economy. Yet the estimate of a larger population leads inexorably to the presumption of an expanded continental economy and of substantial sectors of regional and local exchange networks. Should Africa before the twentieth century continue to be seen as a continent of land surplus and labor shortage? Or should it be viewed as a region of relatively dense population where land was better seen as a scarce resource than a free good?[158]

Study of the forms and dynamics of African money can facilitate the required rethinking of exchange in African markets. It is noteworthy that gold served as currency in the large portions of West Africa where it was mined, and gold also served as currency in Southeast Africa and along the Swahili coast. Silver presented a contrast: silver was the main international currency from the late sixteenth century forth, but silver was little used as currency in sub-Saharan Africa. Partly this was a response to the scarcity of silver in Africa, but it also suggests that Africa was outside the main currents of global trade until the mid-nineteenth century, when silver coins became widely used on many parts of Africa. (An exception to this pattern is Ethiopia and northeast Africa generally—silver was traded and coined in that region, reflecting its integration into Middle East and Indian Ocean trading circuits.)

The logic of the "informal economy," widely applied in the contemporary era, may be useful in portraying some dimensions of the African domestic economy over the centuries. A substantial literature has grown up centering on contemporary economic activity that takes place outside of the formal sector of wages, profits, and regulation—work and transactions that enable people to survive and sometimes prosper, but which escape formal economic accounting.[159] In effect, the informal sector has been treated as marginal to the formal economy and perhaps derivative from it. Another approach would be to treat the "informal" sector as the current version of what was earlier the domestic and regional market of Africa. That is, the lessons that have been learned in study of the contemporary informal sector might be applied to earlier times, and might help explain how a large African population could have sustained a lively regional economy that nonetheless had little interaction with global commerce.

Cross-sectional ethnographic analysis provides another approach for exploring the dynamics of the continental and regional African economy. This approach was adopted at a global level by economist Frederic Pryor in his 1977 *The Origins of the Economy*. Drawing on ethnographic accounts from the Human Relations Area Files, Pryor analyzed four types of distribution systems in peasant economies and found correlations suggesting surprisingly complex processes of economic choice and evolution.[160]

Turning from economic to social implications of the new and higher estimates of African population, it may be that significant insights will come from a rereading of John Iliffe's

[158] Gemery and Hogendorn interpretation of slave exports in terms of "vent for surplus" theory was one of the few arguments of its time that land rather than labor was in short supply in the era of slave trade. Gemery and Hogendorn 1974.
[159] MacGaffey and others.
[160] Pryor 1977. A parallel study relying on HRAF records was that of Patterson 1982(?)..

remarkably broad review, *The African Poor*. In this continental study of poverty in the nineteenth and twentieth centuries, Iliffe distinguished between the poor and the very poor, where the latter never escaped the fringes of hunger.(Iliffe1987) The question is how far into the past this analysis of poverty might be carried.

Did the conditions of African life worsen in the era of slave trade? Did general mortality rates rise in West and Central Africa from the seventeenth to the nineteenth century and in nineteenth-century East Africa? It is certainly the case that enslavement, drought, famine, and epidemic reinforced one another periodically to the point that it becomes difficult to distinguish the various causes of misery.(Miller; Patterson; Jensen) The savanna regions of West Africa and Angola were particularly vulnerable to such downturns, but social tumult and the creation of refugee populations brought periodic turmoil to many African regions. For instance, the turmoil of the Congo basin and north Central Africa in the early colonial years, under King Leopold's Congo Free State and in the French Congo, each succeeded a period of several decades of intensive slave raiding. Investigators of the emergence of the HIV virus in humans continue to explore the question of whether it was just this social disorder that led to the transfer of viruses among species and the formation of the human-carried version of HIV.

The new estimates raise parallel questions about states and statecraft in Africa. While Africans had states throughout the continent, these states in general did not develop the bureaucracies, armies, and monuments of those in Eurasia. Indeed, the scarcity of such great states is one of the reasons why scholars have tended to assume that African populations were sparse. Quite a different possibility is that African societies found ways to develop and nourish dense populations without giving such support to elite classes and state institutions. On a related issue, it may be that the character of African statecraft changed significantly as enslavement grew in significance. That is, the earlier linkage of localized states to the welfare of the monarch's constituents came to be replaced by more warlike and hierarchical states. Meanwhile, the expansion of enslavement put a premium on effective defense and on the maintenance of refugee communities, which again undermined respect for large states.

What was the size of slave populations in Africa? This analysis has argued that the enslaved populations of Africa grew sharply in the eighteenth century and then grew again even more sharply in the nineteenth century. It seems certain that the worldwide peak in enslaved populations came in roughly 1850, and that those in Africa were the majority of those held in slavery. These are demographic projections, however, rather than descriptions of individual lives, so that much more research will be necessary to verify the validity and the meaning of this assertion.

In sum, this assembly of evidence and analysis suggests that we should develop a modified perspective on the overall characteristics of African population in the early modern era. That is, we should envision African populations that were relatively dense, in comparison with others of their time, but which lived under marginal and precarious conditions. Mortality was high on a world scale and there was little development of elite strata. The application of diversified technologies permitted relatively intensive exploitation of varying environments. The expansion of slave trade and a concomitant expansion in domestic slavery, in region after region of the continent, transformed and further marginalized this socio-economic system but did not

destroy it. It may be that the same pattern has been propagated into the present, though it cannot yet be said by what mechanisms the system was reproduced over time.

It is striking, however, that in the early twenty-first century, the African regions in which the incidence of polygyny is highest and the level of female education is lowest are the same regions as those from which the export of male slaves was most consistent and longest lasting: West Africa and Central Africa. Can it be that centuries of slave exports and uneven adult gender balance built a system relying on subordination of women?

One can extend this reasoning by comparing West Africa and East Africa in the eighteenth and nineteenth centuries. In eighteenth-century West Africa, transatlantic slave trade expanded steadily and trans-Saharan slave trade expanded to a lesser degree; eighteenth-century East Africa remained in a situation of relative autarky. In nineteenth-century West Africa, the Atlantic trade declined while the trans-Saharan slave trade expanded somewhat and enslavement within the region expanded as well. In nineteenth-century East Africa, Indian Ocean slave trade grew rapidly to a peak late in the century, then came almost to an end at the end of the century. In West Africa, the nineteenth-century decline in Atlantic slave trade coincided with a rapid growth in commodity exports; commodity exports from East Africa expanded considerably later. Overall, it appears that West Africa rebounded first from the negative demographic effects of slave trade, followed by Central Africa and then by East Africa. But the East African slave trade, though brutal in its impact, lasted for a shorter time than that for West and Central Africa, so the continuing social markers of the slave past seem clearer in West and Central Africa. In East Africa, Mozambique and Malawi are the regions that show the most after-effects of enslavement.

Africa in global context

This analysis sharply contests the widely held notion that African population developed from a very small base in medieval times and expanded steadily—at a rate more rapid than the average of human population growth—until the twentieth century. It is definitely the case that African population since 1950 has grown at rates higher than the average for humanity, but that pattern cannot reasonably be projected into earlier times, and for three main reasons. First, there is no reason to assume that African growth rates were among the highest in the world either before or during the era of the slave trade; second, the effects of enslavement seriously reduced the ability of African populations to grow; and third, general African mortality was relatively high, so that precolonial African growth rates may well have been lower than for other regions. To further test and document this line of argument, we need to expand research on long-term African population patterns, working especially in archaeology, linguistics, social and anthropological studies, and with written documents.

The African continent appeared from the outside to have participated only to a modest degree in the global interactions and changes of the era from 1500 to 1650, though the continent may have undergone major changes that are not yet fully understood – impact of disease is one possibility. The continent was seriously drained in population through enslavement from 1650 to 1850. African migration continued after 1850 as enslavement sent many captives to destinations within Africa and across the Sahara and into the Indian Ocean—though expanding migration from Europe and Asia overshadowed African migration after 1850. From 1850 to 1950 Africa

fell increasingly under European colonial rule, with its mix of repression, taxation, and economic transformation. Throughout all these periods, relatively dense African populations met consistent limits that prevented any long-term growth. With independence after 1950, African nations experienced bursts of development in health, education, and economic growth, but fell into a pattern of neocolonial subordination to international organizations, as with the World Bank's structural adjustment programs. In this last period, however, African populations escaped their previous limits and grew steadily at rates over 2.5% per year, a growth rate high enough to create its own problems.

While the limits on African demographic growth were overcome in the mid-twentieth century, the limits on African economic growth remained in place. From 1850 if not before, African prices and wages in international markets have been held at extremely low levels. Investment in the continent has been overwhelmingly out of domestic funds—yet the African funds available for investment that were restricted by the low incomes that Africans gained in international transactions. Still, African economies have undergone transformations and even growth over the past century, which tends to argue that the domestic economy continues to have a viable mechanism of accumulation.(Manning 1990, pp. 218-219) The population of the African continent is now—and perhaps once again—near to one sixth of the total of humanity, and the distinctive long-term history of its demographic, economic, and social life may have important lessons for the continent itself and for those beyond it.

Appendices (p. 174)

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G. Projected populations (ch 10-11)

Appendix A.

Manning Publications on African Population History

1979. "The Slave Trade in Southern Dahomey, 1640-1890." Henry A. Gemery and Jan S. Hogendorn, eds., The Uncommon Market: Essays in the Economic History of the Atlantic Slave Trade (New York: Academic Press), 109-141.

1981. "The Enslavement of Africans: A Demographic Model." Canadian Journal of African Studies 15, 3, pp. 499-526.

1982. Slavery, Colonialism, and Economic Growth in Dahomey, 1640-1960 (Cambridge: Cambridge University Press, 1982). Finalist for the Herskovits Prize of the African Studies Association. Hardcover.

1982. "A Demographic Model of African Slavery." Christopher Fyfe and David McMaster, eds., African Historical Demography, Vol. 2 (Edinburgh: African Studies Centre), 371-384.

1983. "Contours of Slavery and Social Change in Africa." American Historical Review 88, 4, pp. 835-57

1986. "Slave Trade, 'Legitimate' Trade, and Imperialism Revisited: The Control of Wealth in the Bights of Benin and Biafra." Paul E. Lovejoy, ed., Africans in Bondage: Essays in Honor of Philip D. Curtin (Madison), 203-233.

1987. "Local versus Regional Impact of Slave Exports on Africa." Dennis D. Cordell and Joel W. Gregory, eds., African Population and Capitalism: Historical Perspectives (Boulder: Westview), 35-49.

1988a. "Divining the Unprovable: Simulating the Demography of African Slavery." Journal of Interdisciplinary History 19, 2, pp. 177-201. Co-authored with William S. Griffiths.

1988. "The Impact of Slave Trade Exports on the Population of the Western Coast of Africa, 1700-1850." Serge Daget, ed., De la Traite a l'esclavage, 2 vols. (Paris, Societe francaise d'histoire d'Outre-Mer), II:111-34.

1988. "The Anthropology of Slavery." African Economic History 17, pp. 147-52.

1990. Slavery and African Life: Occidental, Oriental, and African Slave Trades (Cambridge: Cambridge University Press, 1990). A study of the impact of slave exports on African demography, economics, society, and ideology. Paper and hardcover.

1990. "Slavery and the Slave Trade in Colonial Africa." Journal of African History 31, 1, pp. 135-40.

1990. "Slave Trade: The Formal Demography of a Global System." Social Science History 14, 2, pp. 255-79.

1994a. "The Impact of the Slave Trade on the Societies of West and Central Africa." Anthony Tibbles, ed., Transatlantic Slavery: Against Human Dignity (London, 1994), 97-104.

1996. Slave Trades, 1500-1800: Globalization of Forced Labour (Variorium: Aldershot, Great Britain, 1996). Volume 15 of An Expanding World, edited by A. J. Russell-Wood. I am editor of this collection of articles, to which I have written an introduction. Hardcover.

1996a. "Introduction." Patrick Manning, ed., Slave Trades, 1500-1800: Globalization of Forced Labour (Ashgate: Variorum, 1996), xv-xxxiv.

1997. "The Advantages and Limitations of Simulation in Analysing the Slave Trade." Robin Law, ed., Source Material for Studying the Slave Trade and the African Diaspora (Centre of Commonwealth Studies, Univrsity of Stirling, Occasional Paper Number 5, December 1997), pp. 69-78.
1998. "La traite négrière et l'évolution démographique de l'Afrique." Doudou Diène, ed., La chaine et le lien : Une vision de la traite négrière (Paris: UNESCO, 1998), pp. 153-73.
2006a. "Slavery and Slave Trade in West Africa, 1450-1930." Emmanuel Akyeampong, ed, Themes in West Africa's History (Oxford: James Currey), pp. 99-117.
2010. "African Population: Projections, 1851-1961." Karl Ittmann, Dennis D. Cordell, and Gregory Maddox, eds., The Demographics of Empire: The Colonial Order and the Creation of Knowledge,(Athens, OH: Ohio University Press, 2010), pp. 245-275
2014. "African Population, 1650-2000: Comparisons and Implications of New Estimates." In Emmanuel Akyeampong, Robert Bates, Nathan Nunn, and James Robinson, eds., Africa's Development in Historical Perspective.

Appendix B. Variant 2

These are the levels of annual continental enslavement, by region, calculated in Variant 2.

	1800s	1810s	1820s	1830s	1840s	1850s	1860s	1870s	1880s	1890s
Senegambia	3834	5626	6734	7336	7360	7668				
Upper Guinea	3310	6637	6123	4224	4561	5906	6456			
Grain Coast	1485	2733	2558	2752	2970	2970	2970	2970	2970	
Gold Coast	7264	9268	14364	14315	14374	14528				
Bight of Benin	8827	10683	12654	13018	11778	15619	16275	16654	16654	
Bight of Biafra	10905	17242	14487	16447	21138	21742	21810	21810	21810	
Loango	5290	11842	16178	28053	27082	31629	31994	32356	32356	
Angola	24241	20639	25978	36605	41995	47649	50350	51956	51956	
Mozambique	9291	18645	31238	34692	45509	41263	47476	54476	42476	57476
Madagascar	1500	4160	6320	5320	4802	4320	4320	4320	4320	4070
Tanzania	3000	14000	20000	30000	40000	4000	41309	40000	50000	51000
Kenya										
Horn	3900	4300	4300	4300	4300	4300	4300	4400	4550	8000
Eastern Sudan	3520	4620	10120	10120	13420	15620	23100	42900	45650	45650
Chad						2000	2000	2000	2000	2000
Central Sudan	8400	8400	4300	11200	10400	10800	12800	14600	14600	15700
Western Sudan	4950	4950	10120	4950	4950	4950	6050	6050	8800	9350
Total	99,217	143,725	184,404	223,332	254,657	270,964	271,210	294,492	298,142	193,246

Appendix B. Variant 3.

This is a summary of output from the spreadsheets used to calculate the results of Variant 3.

	1790 Exports	1790 Enslaved continent	1800 Exports	1800 Enslaved continent	1810 Exports	1810 Enslaved continent	1820 Exports	1820 Enslaved continent
Senegambia	2,293	11,689	3,834	11689	2,042	11,689	934	11,689
Upper Guinea (SL)	3,310	19,421	2,624	38841	497	38,841	2,396	38,841
Grain (Windward) Coast	1,572	8,582	1,485	8582	237	8,582	412	8,582
Gold Coast	7,269	17,120	5,260	34239	164	34,239	213	17,120
Bight of Benin	8,578	9,005	8,327	22512	5,971	22,512	4,000	45,023
Bight of Biafra	13,931	36,459	10,905	72919	4,568	72,919	7,323	145,838
Loango	10,507	39,160	5,290	78319	11,842	117,479	16,178	78,319
Angola	19,127	21,601	24,241	86404	20,639	86,404	25,378	86,404
W. Sudan	3,025	28,267	4,950	28267	4,950	28,267	4,950	22,613
C. Sudan	1,650	154,692	5,500	154692	5,500	77,346	5,500	77,346
Chad		44,190		22095		11,047		11,047
C. Sudan + Chad	1,650	198,882	5,500	176787	5,500	41,928	5,500	88,394
E. Sudan	4,620	59,912	1,881	29956	1,881	59,912	1,881	119,824
Horn	3,800	139,760	3,900	27952	4,300	27,952	4,300	41,928
Kenya		44,296		44296		44,296		44,296
Tanganyika	800	41,706	3,000	16682	14,000	16,682	14,000	41,706

	1830 Export	1830 Enslaved continent	1840 Export	1840 Enslaved continent	1850 Export	1850 Enslaved continent	1860 Export	1860 Enslaved continent
Senegambia	332	23,377	308	23,377		23,377		2,338
Upper Guinea (SL)	2,059	38,841	714	58,262	164	38,841		19,421
Grain (Windward) Coast	218	8,582		8,562		8,582		8582
Gold Coast	154	17,120		17,120		17,120		13,696
Bight of Benin	3,636	135,069	4,816	90,046	1,035	90,046	379	45,023
Bight of Biafra	5,363	72,919	672	72,919	68	72,919		36,459
Loango	4,303	78,319	5,274	117,479	727	156,639	362	78,319

Angola	15,351	86,404	9,961	86,404	4,367	85,404	1,606	43,202
W. Sudan	4,950	28,267	4,950	28,267	4,950	113,067	3,850	169,600
C. Sudan	5,500	154,692	5,500	154,692	4,400	154,692	4,400	154,692
Chad		11,047		11,047		22,095		22,095
C. Sudan + Chad	5,500	165,740	5,500	165,740	4,400	176,787	4,400	176,787
E. Sudan	1,881	119,824	1,881	119,824	1,881	59,912	1,661	119,824
Horn	4,300	69,880	4,300	69,880	4,300	139,760	4,300	69,880
Kenya		88,592		88,592		88,592		88,592
Tanganyika	30,000	125,118	20,000	125,606	20,000	166,824	18,691	166,824

	1870 Export	1870 Enslaved continent	1880 Export	1880 Enslaved continent	1890 Exports	1890 Enslaved continent
Senegambia		2338		0		
Upper Guinea (SL)		19,421		38841		
Grain (Windward) Coast		3433		17165		
Gold Coast		6848		3424		
Bight of Benin		45,023		45,023		9005
Bight of Biafra		36,459		7292		7292
Loango		156,639		78,319		7832
Angola		86,404		43,202		21601
W. Sudan	3,850	169,600	1,100	169,600		169,600
C. Sudan	2,200	154,692	2,200	309,385	1,100	154,692
Chad		22,095		44,190		44,190
C. Sudan + Chad	2,200	176,787		353,574	1,100	198,882
E. Sudan	1,661	119,824	550	119,824	550	59,912
Horn	4,200	139,760	4,050	139,760	600	139,760
Kenya		88,592		44,296		44,296
Tanganyika	20,000	166,824	10,000	41,706	9,000	41,706

Appendix C.

Twentieth-Century Input Data

Populations 1950, 1960 (to 2000)

Estimates by table.

Appendix D.

R-language Simulation Program

```
setwd("~/Desktop/African Population/African_Popt")


windDefault<-function(){

  currentSource<-as.matrix(read.table(file="ps3r002a.dat",skip=1))
  dim(currentSource)<-c(17,2)
  currentCaptor<-as.matrix(read.table(file="ps3r002b.dat",skip=1))
  dim(currentCaptor)<-c(17,2)
  sourceFert<-as.matrix(read.table(file="f29g2794.dat",skip=1))
  dim(sourceFert)<-c(17,1)
  captorFert<-as.matrix(read.table(file="f29g2794.dat",skip=1))
  dim(captorFert)<-c(17,1)
  domestFert<-as.matrix(read.table(file="f29g2444.dat",skip=1))
  dim(domestFert)<-c(17,1)
  exportFert<-as.matrix(read.table(file="f29g2444.dat",skip=1))
  dim(exportFert)<-c(17,1)
  newDomFert<-as.matrix(read.table(file="f29g2094.dat",skip=1))
  dim(newDomFert)<-c(17,1)
  newAfrExpFert<-as.matrix(read.table(file="f29g2094.dat",skip=1))
  dim(newAfrExpFert)<-c(17,1)
  newAbrExpFert<-as.matrix(read.table(file="f29g2094.dat",skip=1))
  dim(newAbrExpFert)<-c(17,1)
  sourceSurv<-as.matrix(read.table(file="ss3e1l0.dat",skip=1))
  dim(sourceSurv)<-c(18,2)
  captorSurv<-as.matrix(read.table(file="ss3e1l0.dat",skip=1))
  dim(captorSurv)<-c(18,2)
  domestSurv<-as.matrix(read.table(file="ss2e1l0.dat",skip=1))
  dim(domestSurv)<-c(18,2)
  exportSurv<-as.matrix(read.table(file="ss2e1l0.dat",skip=1))
  dim(exportSurv)<-c(18,2)
  capAfrSurv<-as.matrix(read.table(file="sw4e5l8.dat",skip=1))
  dim(capAfrSurv)<-c(18,2)
  capAbrSurv<-as.matrix(read.table(file="sw4e5l8.dat",skip=1))
  dim(capAbrSurv)<-c(18,2)
  captureSize<-as.matrix(read.table(file="c241p13.dat",skip=1))
  dim(captureSize)<-c(17,2)

  defaultArray<-numeric(18*2*16)
  dim(defaultArray)<-c(18,2,16)
  defaultArray[1:17,,1]<-currentSourceChapte
  defaultArray[1:17,,2]<-currentCaptor
  defaultArray[1:17,1,3]<-sourceFert
  defaultArray[1:17,1,4]<-captorFert
```

```
  defaultArray[1:17,1,5]<-domestFert
  defaultArray[1:17,1,6]<-exportFert
  defaultArray[1:17,1,7]<-newDomFert
  defaultArray[1:17,1,8]<-newAfrExpFert
  defaultArray[1:17,1,9]<-newAbrExpFert
  defaultArray[,,10]<-sourceSurv
  defaultArray[,,11]<-captorSurv
  defaultArray[,,12]<-domestSurv
  defaultArray[,,13]<-exportSurv
  defaultArray[,,14]<-capAfrSurv
  defaultArray[,,15]<-capAbrSurv
  defaultArray[1:17,,16]<-captureSize

  return(defaultArray)
}

terrType1<-function(defaultArray,partArray,decData,numIter,numDec,firstDec){

  ##############################################################################################
  ##  Initialize aggregate output storage
  ##############################################################################################
  exportArray<-numeric(numDec*17*2)
  dim(exportArray)<-c(numDec,17,2)
  decPopVect<-numeric(numDec)
  sexNAFEpop<-numeric(numDec)
  sexNABEpop<-numeric(numDec)

  ##############################################################################################
  ##  Initialize territorial output storage
  ##############################################################################################
  allRegPopTracker<-numeric(numDec*17*2*numIter)
  dim(allRegPopTracker)<-c(numDec,17,2,numIter)
  allDomPopTracker<-numeric(numDec*17*2*numIter)
  dim(allDomPopTracker)<-c(numDec,17,2,numIter)
  allNDPopTracker<-numeric(numDec*17*2*numIter)
  dim(allNDPopTracker)<-c(numDec,17,2,numIter)
  allNAEPopTracker<-numeric(numDec*17*2*numIter)
  dim(allNAEPopTracker)<-c(numDec,17,2,numIter)
  allExportTracker<-numeric(numDec*17*2*numIter)
  dim(allExportTracker)<-c(numDec,17,2,numIter)
  newBirths<-numeric(numDec)
  newDeaths<-numeric(numDec)

  ##############################################################################################
  ##        Convert decData to the appropriate format
  ##############################################################################################
  terr<-as.character(decData[1])
  peakDec<-as.numeric(decData[5])
  zeroDec<-as.numeric(decData[6])
  postPeakCapt<-as.numeric(decData[7])
  initPop<-as.numeric(decData[8])
  decExports<-as.numeric(decData[9:33])
  decs<-seq(firstDec,firstDec-10*(numDec-1),by=-10)
  switch1<-which(decs==zeroDec)-1
  switch2<-which(decs==peakDec)
  methodByDec<-c(rep(0,switch1),rep(1,switch2-switch1),rep(2,(numDec-switch2)))
```

```
  mostRecentPop<-initPop
  for(j in 1:numDec){


    ##export driven slaving
    print(decExports[j])
    if(decExports[j]>0){
      currCaptMult<-1
      currPartMult<-1
      precisionRatio<-0
      maxIter<-0

      while((abs(precisionRatio-1)>.05)&(maxIter<5)){
        callToSim<-
standardSim2.1(defaultArray,partArray,currCaptMult,currPartMult,postPeakCapt,decExports[j],mostRecentPop,nu
mIter)
        allRegPopTracker[j,,,]<-callToSim$ARPT
        allDomPopTracker[j,,,]<-callToSim$ADPT
        allExportTracker[j,,,]<-callToSim$AEPT
        allNDPopTracker[j,,,]<-callToSim$ANDPT
        allNAEPopTracker[j,,,]<-callToSim$ANAEPT
        birthTracker<-callToSim$BT
        deathTracker<-callToSim$DT
        captiveTracker<-callToSim$CT
        exportTracker<-callToSim$ET
        currCaptMult<-callToSim$CCM
        if (currCaptMult == 0){currCaptMult <- .01}
        precisionRatio<-callToSim$PR
        maxIter<-maxIter+1
      }
      endPopRatio<-mostRecentPop/sum(allRegPopTracker[j,,,numIter])
      allRegPopTracker[j,,,]<-allRegPopTracker[j,,,]*endPopRatio
      allDomPopTracker[j,,,]<-allDomPopTracker[j,,,]*endPopRatio
      allExportTracker[j,,,]<-allExportTracker[j,,,]*endPopRatio
      allNDPopTracker[j,,,]<-allNDPopTracker[j,,,]*endPopRatio
      allNAEPopTracker[j,,,]<-allNAEPopTracker[j,,,]*endPopRatio
      exportArray[j,,]<-allExportTracker[j,,,numIter-1]+allExportTracker[j,,,numIter]
      mostRecentPop<-sum(allRegPopTracker[j,,,numIter-2])
      decPopVect[j]<-mostRecentPop
      newBirths[j]<-(sum(birthTracker[numIter-1,])+sum(birthTracker[numIter,]))*endPopRatio
      newDeaths[j]<-(sum(deathTracker[numIter-1,])+sum(deathTracker[numIter,]))*endPopRatio
    }
    if(decExports[j]==0){
      callToSim<-simpleSim(defaultArray,numIter)
      allRegPopTracker[j,,,]<-callToSim$ARPT
      birthTracker<-callToSim$BT
      deathTracker<-callToSim$DT
      captiveTracker<-callToSim$CT
      exportTracker<-callToSim$ET
      endPopRatio<-mostRecentPop/sum(allRegPopTracker[j,,,numIter])
      allRegPopTracker[j,,,]<-allRegPopTracker[j,,,]*endPopRatio
      mostRecentPop<-sum(allRegPopTracker[j,,,numIter-2])
      decPopVect[j]<-mostRecentPop
      newBirths[j]<-(birthTracker[numIter-1]+birthTracker[numIter])*endPopRatio
      newDeaths[j]<-(deathTracker[numIter-1]+deathTracker[numIter])*endPopRatio
```

```
  }
 }


 for (k in 1:numDec){
  if((sum(allNAEPopTracker[k,,1,numIter-2])+sum(allNAEPopTracker[k,,2,numIter-2]))==0){
   sexNAFEpop[j]<-0
  }
  else{
   sexNAFEpop[k]<-(sum(allNAEPopTracker[k,,2,numIter-2]))/(sum(allNAEPopTracker[k,,1,numIter-
2])+sum(allNAEPopTracker[k,,2,numIter-2]))
  }



 }

 ##############################################################################################
 ##       Territorial output
 ##############################################################################################
 forRates<-cbind(initPop,decPopVect)
 midPeriodPops<-(forRates[1:(length(forRates)-1)]+forRates[2:length(forRates)])/2
 arpt<-allRegPopTracker[,,,numIter-2]
 adpt<-allDomPopTracker[,,,numIter-2]
 andpt<-allNDPopTracker[,,,numIter-2]
 anaept<-allNAEPopTracker[,,,numIter-2]

 temp<-data.frame(Region=terr)
 write.table(temp,paste("",terr,".csv",sep=""),row.names = FALSE, col.names = TRUE)
 for(z in 1:numDec){
  temp<-data.frame(Year=decs[z])
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(AdultSexRatio=c(sum(arpt[z,4:11,2])/sum(arpt[z,3:8,1]),"DomesticSlavePopulation"))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(Female=adpt[z,,1],Male=adpt[z,,2])
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE, sep=",")
  temp<-data.frame(TotalDomesticFemaleSlaves=sum(adpt[z,,1]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalDomesticMaleSlaves=sum(adpt[z,,2]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalDomesticSlaves=c(sum(adpt[z,,]),"NewDomesticSlavePopulation"))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(Female=andpt[z,,1],Male=andpt[z,,2])
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE, sep = ",")
  temp<-data.frame(TotalNewDomesticFemaleSlaves=sum(andpt[z,,1]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalNewDomesticMaleSlaves=sum(andpt[z,,2]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalNewDomesticSlaves=c(sum(andpt[z,,]),"NewAfricanExportSlavePopulation"))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(Female=anaept[z,,1],Male=anaept[z,,2])
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE, sep=",")
  temp<-data.frame(TotalNewAfricanExportFemaleSlaves=sum(anaept[z,,1]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalNewAfricanExportMaleSlaves=sum(anaept[z,,2]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
```

```
   temp<-data.frame(TotalNewAfricanExportSlaves=sum(anaept[z,,]))
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualBirths=newBirths[z]/10)
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualBirthRate=newBirths[z]/(10*midPeriodPops[z]))
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualDeaths=newDeaths[z]/10)
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualDeathRate=c(newDeaths[z]/(10*midPeriodPops[z]),""))
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  }
  return(list(exportArray=exportArray,decPopVect=decPopVect,sexNAFEpop=sexNAFEpop))
}

simpleSim<-function(defaultArray,numIter){

  ARPT<-numeric(17*2*numIter)
  dim(ARPT)<-c(17,2,numIter)
  BT<-numeric(numIter)
  DT<-numeric(numIter)

  defaultArray[1:17,1,4]->captorFert
  defaultArray[,,11]->captorSurv
  defaultArray[1:17,,2]->currentCaptor
  currentCaptor[,2]<-.95109*currentCaptor[,2]

  for (ii in 1:numIter){
   previousCaptor<-currentCaptor
   currentCaptor<-previousCaptor*captorSurv[2:18,]
   DT[ii]<-sum(previousCaptor-currentCaptor)
   midCaptor<-(previousCaptor+currentCaptor)/2
   births<-midCaptor[3:11,1]*5*captorFert[3:11]
   newFemales<-sum(births)
   newMales<-sum(births)*1.03
   currentCaptor[17,]<-currentCaptor[16,]+currentCaptor[17,]
   currentCaptor[2:16,]<-currentCaptor[1:15,]
   currentCaptor[1,]<-c(newFemales,newMales)*captorSurv[1,]
   BT[ii]<-newFemales+newMales
   DT[ii]<-DT[ii]+sum(c(newFemales,newMales)-currentCaptor[1,])

   ARPT[,,ii]<-currentCaptor

  }
  CT<-0
  ET<-0
  return(list(ARPT=ARPT,BT=BT,DT=DT,CT=CT,ET=ET))
}

standardSim1.1<-
function(defaultArray,partArray,currCaptMult,currPartMult,postPeakCapt,decExports,mostRecentPop,numIter){

  defaultArray[1:17,,1]->currentSource
  defaultArray[1:17,,2]->currentCaptor
  defaultArray[1:17,1,3]->sourceFert
  defaultArray[1:17,1,4]->captorFert
  defaultArray[1:17,1,5]->domestFert
```

```
defaultArray[1:17,1,6]->exportFert
defaultArray[1:17,1,7]->newDomFert
defaultArray[1:17,1,8]->newAfrExpFert
defaultArray[1:17,1,9]->newAbrExpFert
defaultArray[,,10]->sourceSurv
defaultArray[,,11]->captorSurv
defaultArray[,,12]->domestSurv
defaultArray[,,13]->exportSurv
defaultArray[,,14]->capAfrSurv
defaultArray[,,15]->capAbrSurv
defaultArray[1:17,,16]->captureSize

captureSize<-captureSize*currCaptMult
partition<-partArray*currPartMult

currentSource[,2]<-.95109*currentSource[,2]
currentCaptor[,2]<-.95109*currentCaptor[,2]
currentDomestics<-numeric(34)
dim(currentDomestics)<-c(17,2)

ARPT<-numeric(17*2*numIter)
dim(ARPT)<-c(17,2,numIter)
ADPT<-numeric(17*2*numIter)
dim(ADPT)<-c(17,2,numIter)
AEPT<-numeric(17*2*numIter)
dim(AEPT)<-c(17,2,numIter)
BT<-numeric(numIter*5)
dim(BT)<-c(numIter,5)
DT<-numeric(numIter*5)
dim(DT)<-c(numIter,5)
CT<-numeric(numIter)
ET<-numeric(numIter)

for (jj in 1:numIter){
  previousSource<-currentSource
  currentSource<-previousSource*sourceSurv[2:18,]
  DT[jj,1]<-sum(previousSource-currentSource)
  midSource<-(previousSource+currentSource)/2
  captives<-midSource*5*captureSize
  currentSource<-currentSource-captives
  midSource<-(previousSource+currentSource)/2
  births<-midSource[3:11,1]*5*sourceFert[3:11]
  newFemales<-sum(births)
  newMales<-sum(births)*1.03
  currentSource[17,]<-currentSource[16,]+currentSource[17,]
  currentSource[2:16,]<-currentSource[1:15,]
  currentSource[1,]<-c(newFemales,newMales)*sourceSurv[1,]
  BT[jj,1]<-newFemales+newMales
  DT[jj,1]<-DT[jj,1]+sum(c(newFemales,newMales)-currentSource[1,])

  CT[jj]<-sum(captives)

  previousCaptor<-currentCaptor
  currentCaptor<-previousCaptor*captorSurv[2:18,]
  DT[jj,2]<-sum(previousCaptor-currentCaptor)
  midCaptor<-(previousCaptor+currentCaptor)/2
```

```
    births<-midCaptor[3:11,1]*5*captorFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentCaptor[17,]<-currentCaptor[16,]+currentCaptor[17,]
    currentCaptor[2:16,]<-currentCaptor[1:15,]
    currentCaptor[1,]<-c(newFemales,newMales)*captorSurv[1,]
    BT[jj,2]<-newFemales+newMales
    DT[jj,2]<-DT[jj,2]+sum(c(newFemales,newMales)-currentCaptor[1,])

    previousNewDomestics<-captives*(1-partition)
    currentNewDomestics<-
previousNewDomestics*sourceSurv[2:18,]^.5*capAfrSurv[2:18,]*domestSurv[2:18,]^(3/10)
    DT[jj,3]<-sum(previousNewDomestics-currentNewDomestics)
    midNewDomestics<-(previousNewDomestics+currentNewDomestics)/2
    births<-midNewDomestics[3:11,1]*(2.5*sourceFert[3:11]+1.5*newDomFert[3:11]+1*domestFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewDomestics[17,]<-currentNewDomestics[16,]+currentNewDomestics[17,]
    currentNewDomestics[2:16,]<-currentNewDomestics[1:15,]
    currentNewDomestics[1,]<-c(newFemales,newMales)*sourceSurv[1,]^.5*capAfrSurv[1,]*domestSurv[1,]^(3/10)
    BT[jj,3]<-newFemales+newMales
    DT[jj,3]<-DT[jj,3]+sum(c(newFemales,newMales)-currentNewDomestics[1,])

    previousDomestics<-currentDomestics
    currentDomestics<-previousDomestics*domestSurv[2:18,]
    DT[jj,4]<-sum(previousDomestics-currentDomestics)
    midDomestics<-(previousDomestics+currentDomestics)/2
    births<-midDomestics[3:11,1]*5*domestFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
    currentDomestics[2:16,]<-currentDomestics[1:15,]
    currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
    currentDomestics<-currentDomestics+currentNewDomestics
    BT[jj,4]<-newFemales+newMales
    DT[jj,4]<-DT[jj,4]+sum(c(newFemales,newMales)-currentDomestics[1,])

    previousNewAbrExp<-captives*partition
    currentNewAbrExp<-
previousNewAbrExp*sourceSurv[2:18,]^(1/2)*capAfrSurv[2:18,]*capAbrSurv[2:18,]*exportSurv[2:18,]^(1/10)
    DT[jj,5]<-sum(previousNewAbrExp-currentNewAbrExp)
    midNewAbrExp<-(previousNewAbrExp+currentNewAbrExp)/2
    births<-
midNewAbrExp[3:11,1]*(2.5*sourceFert[3:11]+newAfrExpFert[3:11]+newAbrExpFert[3:11]+.5*exportFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewAbrExp[17,]<-currentNewAbrExp[16,]+currentNewAbrExp[17,]
    currentNewAbrExp[2:16,]<-currentNewAbrExp[1:15,]
    currentNewAbrExp[1,]<-
c(newFemales,newMales)*sourceSurv[1,]^(1/2)*capAfrSurv[1,]*capAbrSurv[1,]*exportSurv[1,]^(1/10)
    BT[jj,5]<-newFemales+newMales
    DT[jj,5]<-DT[jj,5]+sum(c(newFemales,newMales)-currentNewAbrExp[1,])

    ET[jj]<-sum(currentNewAbrExp)

    ARPT[,,jj]<-currentSource+currentCaptor+currentDomestics
```

```
   ADPT[,,jj]<-currentDomestics
   AEPT[,,jj]<-currentNewAbrExp
  }

  endPopRatio<-mostRecentPop/sum(ARPT[,,numIter])
  defCaptives<-(CT[numIter-1]+CT[numIter])*endPopRatio
  defExports<-(ET[numIter-1]+ET[numIter])*endPopRatio
  PR<-defCaptives/postPeakCapt
  captCptvRela<-getCaptCptvRela(defaultArray,captureSize,partition,numIter)
  CCM<-captCptvRela[which.min(abs(postPeakCapt/defCaptives-captCptvRela[,2])),1]*currCaptMult
  CT<-defCaptives
  ET<-defExports

  return(list(ARPT=ARPT,ADPT=ADPT,AEPT=AEPT,BT=BT,CT=CT,DT=DT,ET=ET,CCM=CCM,PR=PR))
}

getCaptCptvRela<-function(defaultArray,capture,partition,numIter){

  captRela<-numeric(2*301)
  dim(captRela)<-c(301,2)
  captRela[,1]<-seq(0,3,by=.01)

  defaultArray[1:17,1,3]->sourceFert
  defaultArray[1:17,1,4]->captorFert
  defaultArray[1:17,1,5]->domestFert
  defaultArray[1:17,1,6]->exportFert
  defaultArray[1:17,1,7]->newDomFert
  defaultArray[1:17,1,8]->newAfrExpFert
  defaultArray[1:17,1,9]->newAbrExpFert
  defaultArray[,,10]->sourceSurv
  defaultArray[,,11]->captorSurv
  defaultArray[,,12]->domestSurv
  defaultArray[,,13]->exportSurv
  defaultArray[,,14]->capAfrSurv
  defaultArray[,,15]->capAbrSurv

  for(kk in captRela[,1]){
   defaultArray[1:17,,1]->currentSource
   defaultArray[1:17,,2]->currentCaptor

   captureSize<-kk*capture

   currentSource[,2]<-.95109*currentSource[,2]        ##        modify males according to initial sex ratio = .95109
   currentCaptor[,2]<-.95109*currentCaptor[,2]

   ##############################################################################
   ##      necessary declarations and initializations for the simulation
   ##############################################################################

   currentNewDomestics<-numeric(34)
   dim(currentNewDomestics)<-c(17,2)
   currentDomestics<-numeric(34)
   dim(currentDomestics)<-c(17,2)
   currentNewAfrExp<-numeric(34)
   dim(currentNewAfrExp)<-c(17,2)
   currentNewAbrExp<-numeric(34)
```

```
  dim(currentNewAbrExp)<-c(17,2)
  captiveTracker<-numeric(2)

  ##############################################################################
  ##      Begin the first iteration through 5 year periods of time
  ##############################################################################

  for (iii in 1:numIter){
    previousSource<-currentSource
    currentSource<-previousSource*sourceSurv[2:18,]
    midSource<-(previousSource+currentSource)/2
    captives<-midSource*5*captureSize
    currentSource<-currentSource-captives
    midSource<-(previousSource+currentSource)/2
    births<-midSource[3:11,1]*5*sourceFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentSource[17,]<-currentSource[16,]+currentSource[17,]
    currentSource[2:16,]<-currentSource[1:15,]
    currentSource[1,]<-c(newFemales,newMales)*sourceSurv[1,]

    if(iii==(numIter-1))captiveTracker[1]<-sum(captives)
    if(iii==(numIter))captiveTracker[2]<-sum(captives)

    previousCaptor<-currentCaptor
    currentCaptor<-previousCaptor*captorSurv[2:18,]
    midCaptor<-(previousCaptor+currentCaptor)/2
    births<-midCaptor[3:11,1]*5*captorFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentCaptor[17,]<-currentCaptor[16,]+currentCaptor[17,]
    currentCaptor[2:16,]<-currentCaptor[1:15,]
    currentCaptor[1,]<-c(newFemales,newMales)*captorSurv[1,]

    previousNewDomestics<-captives*(1-partition)
    currentNewDomestics<-
previousNewDomestics*sourceSurv[2:18,]^.5*capAfrSurv[2:18,]*domestSurv[2:18,]^(3/10)
    midNewDomestics<-(previousNewDomestics+currentNewDomestics)/2
    births<-midNewDomestics[3:11,1]*(2.5*sourceFert[3:11]+1.5*newDomFert[3:11]+1*domestFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewDomestics[17,]<-currentNewDomestics[16,]+currentNewDomestics[17,]
    currentNewDomestics[2:16,]<-currentNewDomestics[1:15,]
    currentNewDomestics[1,]<-
c(newFemales,newMales)*sourceSurv[1,]^.5*capAfrSurv[1,]*domestSurv[1,]^(3/10)

    previousDomestics<-currentDomestics
    currentDomestics<-previousDomestics*domestSurv[2:18,]
    midDomestics<-(previousDomestics+currentDomestics)/2
    births<-midDomestics[3:11,1]*5*domestFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
    currentDomestics[2:16,]<-currentDomestics[1:15,]
    currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
    currentDomestics<-currentDomestics+currentNewDomestics
```

```
    previousNewAbrExp<-captives*partition
    currentNewAbrExp<-
previousNewAbrExp*sourceSurv[2:18,]^(1/2)*capAfrSurv[2:18,]*capAbrSurv[2:18,]*exportSurv[2:18,]^(1/10)
    midNewAbrExp<-(previousNewAbrExp+currentNewAbrExp)/2
    births<-
midNewAbrExp[3:11,1]*(2.5*sourceFert[3:11]+newAfrExpFert[3:11]+newAbrExpFert[3:11]+.5*exportFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewAbrExp[17,]<-currentNewAbrExp[16,]+currentNewAbrExp[17,]
    currentNewAbrExp[2:16,]<-currentNewAbrExp[1:15,]
    currentNewAbrExp[1,]<-
c(newFemales,newMales)*sourceSurv[1,]^(1/2)*capAfrSurv[1,]*capAbrSurv[1,]*exportSurv[1,]^(1/10)

   }

   captRela[which(captRela[,1]==kk),2]<-sum(captiveTracker)
  }

  captRela[,2]<-captRela[,2]/captRela[which(captRela[,1]==1),2]

  maxCapt<-which.max(captRela[,2])
  captRela<-captRela[1:maxCapt,]

  return(captRela)
}

standardSim1.2<-
function(defaultArray,partArray,currCaptMult,currPartMult,postPeakCapt,decExports,mostRecentPop,numIter){

  defaultArray[1:17,,1]->currentSource
  defaultArray[1:17,,2]->currentCaptor
  defaultArray[1:17,1,3]->sourceFert
  defaultArray[1:17,1,4]->captorFert
  defaultArray[1:17,1,5]->domestFert
  defaultArray[1:17,1,6]->exportFert
  defaultArray[1:17,1,7]->newDomFert
  defaultArray[1:17,1,8]->newAfrExpFert
  defaultArray[1:17,1,9]->newAbrExpFert
  defaultArray[,,10]->sourceSurv
  defaultArray[,,11]->captorSurv
  defaultArray[,,12]->domestSurv
  defaultArray[,,13]->exportSurv
  defaultArray[,,14]->capAfrSurv
  defaultArray[,,15]->capAbrSurv
  defaultArray[1:17,,16]->captureSize

  captureSize<-captureSize*currCaptMult
  partition<-partArray*currPartMult

  currentSource[,2]<-.95109*currentSource[,2]
  currentCaptor[,2]<-.95109*currentCaptor[,2]
  currentDomestics<-numeric(34)
  dim(currentDomestics)<-c(17,2)

  ARPT<-numeric(17*2*numIter)
```

```
  dim(ARPT)<-c(17,2,numIter)
  ADPT<-numeric(17*2*numIter)
  dim(ADPT)<-c(17,2,numIter)
  AEPT<-numeric(17*2*numIter)
  dim(AEPT)<-c(17,2,numIter)
  ANDPT<-numeric(17*2*numIter)
  dim(ANDPT)<-c(17,2,numIter)
  ANAEPT<-numeric(17*2*numIter)
  dim(ANAEPT)<-c(17,2,numIter)
  BT<-numeric(numIter*5)
  dim(BT)<-c(numIter,5)
  DT<-numeric(numIter*5)
  dim(DT)<-c(numIter,5)
  CT<-numeric(numIter)
  ET<-numeric(numIter)

  for (jjj in 1:numIter){
    previousSource<-currentSource
    currentSource<-previousSource*sourceSurv[2:18,]
    DT[jjj,1]<-sum(previousSource-currentSource)
    midSource<-(previousSource+currentSource)/2
    captives<-midSource*5*captureSize
    currentSource<-currentSource-captives
    midSource<-(previousSource+currentSource)/2
    births<-midSource[3:11,1]*5*sourceFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentSource[17,]<-currentSource[16,]+currentSource[17,]
    currentSource[2:16,]<-currentSource[1:15,]
    currentSource[1,]<-c(newFemales,newMales)*sourceSurv[1,]
    BT[jjj,1]<-newFemales+newMales
    DT[jjj,1]<-DT[jjj,1]+sum(c(newFemales,newMales)-currentSource[1,])

    CT[jjj]<-sum(captives)

    previousCaptor<-currentCaptor
    currentCaptor<-previousCaptor*captorSurv[2:18,]
    DT[jjj,2]<-sum(previousCaptor-currentCaptor)
    midCaptor<-(previousCaptor+currentCaptor)/2
    births<-midCaptor[3:11,1]*5*captorFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentCaptor[17,]<-currentCaptor[16,]+currentCaptor[17,]
    currentCaptor[2:16,]<-currentCaptor[1:15,]
    currentCaptor[1,]<-c(newFemales,newMales)*captorSurv[1,]
    BT[jjj,2]<-newFemales+newMales
    DT[jjj,2]<-DT[jjj,2]+sum(c(newFemales,newMales)-currentCaptor[1,])

    previousNewDomestics<-captives*(1-partition)
    currentNewDomestics<-
previousNewDomestics*sourceSurv[2:18,]^.5*capAfrSurv[2:18,]*domestSurv[2:18,]^(3/10)
    DT[jjj,3]<-sum(previousNewDomestics-currentNewDomestics)
    midNewDomestics<-(previousNewDomestics+currentNewDomestics)/2
    births<-midNewDomestics[3:11,1]*(2.5*sourceFert[3:11]+1.5*newDomFert[3:11]+1*domestFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
```

```
    currentNewDomestics[17,]<-currentNewDomestics[16,]+currentNewDomestics[17,]
    currentNewDomestics[2:16,]<-currentNewDomestics[1:15,]
    currentNewDomestics[1,]<-c(newFemales,newMales)*sourceSurv[1,]^.5*capAfrSurv[1,]*domestSurv[1,]^(3/10)
    BT[jjj,3]<-newFemales+newMales
    DT[jjj,3]<-DT[jjj,3]+sum(c(newFemales,newMales)-currentNewDomestics[1,])

    previousDomestics<-currentDomestics
    currentDomestics<-previousDomestics*domestSurv[2:18,]
    DT[jjj,4]<-sum(previousDomestics-currentDomestics)
    midDomestics<-(previousDomestics+currentDomestics)/2
    births<-midDomestics[3:11,1]*5*domestFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
    currentDomestics[2:16,]<-currentDomestics[1:15,]
    currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
    currentDomestics<-currentDomestics+currentNewDomestics
    BT[jjj,4]<-newFemales+newMales
    DT[jjj,4]<-DT[jjj,4]+sum(c(newFemales,newMales)-currentDomestics[1,])

    previousNewAbrExp<-captives*partition
    currentNewAbrExp<-
previousNewAbrExp*sourceSurv[2:18,]^(1/2)*capAfrSurv[2:18,]*capAbrSurv[2:18,]*exportSurv[2:18,]^(1/10)
    DT[jjj,5]<-sum(previousNewAbrExp-currentNewAbrExp)
    midNewAbrExp<-(previousNewAbrExp+currentNewAbrExp)/2
    births<-
midNewAbrExp[3:11,1]*(2.5*sourceFert[3:11]+newAfrExpFert[3:11]+newAbrExpFert[3:11]+.5*exportFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewAbrExp[17,]<-currentNewAbrExp[16,]+currentNewAbrExp[17,]
    currentNewAbrExp[2:16,]<-currentNewAbrExp[1:15,]
    currentNewAbrExp[1,]<-
c(newFemales,newMales)*sourceSurv[1,]^(1/2)*capAfrSurv[1,]*capAbrSurv[1,]*exportSurv[1,]^(1/10)
    BT[jjj,5]<-newFemales+newMales
    DT[jjj,5]<-DT[jjj,5]+sum(c(newFemales,newMales)-currentNewAbrExp[1,])

    ET[jjj]<-sum(currentNewAbrExp)

    ARPT[,,jjj]<-currentSource+currentCaptor+currentDomestics
    ADPT[,,jjj]<-currentDomestics
    AEPT[,,jjj]<-currentNewAbrExp
    ANDPT[,,jjj]<-currentNewDomestics
    ANAEPT[,,jjj]<-currentNewAbrExp
  }

  endPopRatio<-mostRecentPop/sum(ARPT[,,numIter])
  defCaptives<-(CT[numIter-1]+CT[numIter])*endPopRatio
  defExports<-(ET[numIter-1]+ET[numIter])*endPopRatio
  CT<-defCaptives
  ET<-defExports


return(list(ARPT=ARPT,ADPT=ADPT,AEPT=AEPT,ANDPT=ANDPT,ANAEPT=ANAEPT,BT=BT,CT=CT,DT
=DT,ET=ET))
}
```

```
standardSim2.1<-
function(defaultArray,partArray,currCaptMult,currPartMult,postPeakCapt,decExports,mostRecentPop,numIter){

 defaultArray[1:17,,1]->currentSource
 defaultArray[1:17,,2]->currentCaptor
 defaultArray[1:17,1,3]->sourceFert
 defaultArray[1:17,1,4]->captorFert
 defaultArray[1:17,1,5]->domestFert
 defaultArray[1:17,1,6]->exportFert
 defaultArray[1:17,1,7]->newDomFert
 defaultArray[1:17,1,8]->newAfrExpFert
 defaultArray[1:17,1,9]->newAbrExpFert
 defaultArray[,,10]->sourceSurv
 defaultArray[,,11]->captorSurv
 defaultArray[,,12]->domestSurv
 defaultArray[,,13]->exportSurv
 defaultArray[,,14]->capAfrSurv
 defaultArray[,,15]->capAbrSurv
 defaultArray[1:17,,16]->captureSize

 captureSize<-captureSize*currCaptMult
 partition<-partArray*currPartMult

 currentSource[,2]<-.95109*currentSource[,2]
 currentCaptor[,2]<-.95109*currentCaptor[,2]
 currentDomestics<-numeric(34)
 dim(currentDomestics)<-c(17,2)

 ARPT<-numeric(17*2*numIter)
 dim(ARPT)<-c(17,2,numIter)
 ADPT<-numeric(17*2*numIter)
 dim(ADPT)<-c(17,2,numIter)
 AEPT<-numeric(17*2*numIter)
 dim(AEPT)<-c(17,2,numIter)
 ANDPT<-numeric(17*2*numIter)
 dim(ANDPT)<-c(17,2,numIter)
 ANAEPT<-numeric(17*2*numIter)
 dim(ANAEPT)<-c(17,2,numIter)
 BT<-numeric(numIter*5)
 dim(BT)<-c(numIter,5)
 DT<-numeric(numIter*5)
 dim(DT)<-c(numIter,5)
 CT<-numeric(numIter)
 ET<-numeric(numIter)

 for (kkk in 1:numIter){
  previousSource<-currentSource
  currentSource<-previousSource*sourceSurv[2:18,]
  DT[kkk,1]<-sum(previousSource-currentSource)
  midSource<-(previousSource+currentSource)/2
  captives<-midSource*5*captureSize
  currentSource<-currentSource-captives
  midSource<-(previousSource+currentSource)/2
  births<-midSource[3:11,1]*5*sourceFert[3:11]
  newFemales<-sum(births)
  newMales<-sum(births)*1.03
```

```
    currentSource[17,]<-currentSource[16,]+currentSource[17,]
    currentSource[2:16,]<-currentSource[1:15,]
    currentSource[1,]<-c(newFemales,newMales)*sourceSurv[1,]
    BT[kkk,1]<-newFemales+newMales
    DT[kkk,1]<-DT[kkk,1]+sum(c(newFemales,newMales)-currentSource[1,])

    CT[kkk]<-sum(captives)

    previousCaptor<-currentCaptor
    currentCaptor<-previousCaptor*captorSurv[2:18,]
    DT[kkk,2]<-sum(previousCaptor-currentCaptor)
    midCaptor<-(previousCaptor+currentCaptor)/2
    births<-midCaptor[3:11,1]*5*captorFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentCaptor[17,]<-currentCaptor[16,]+currentCaptor[17,]
    currentCaptor[2:16,]<-currentCaptor[1:15,]
    currentCaptor[1,]<-c(newFemales,newMales)*captorSurv[1,]
    BT[kkk,2]<-newFemales+newMales
    DT[kkk,2]<-DT[kkk,2]+sum(c(newFemales,newMales)-currentCaptor[1,])

    previousNewDomestics<-captives*(1-partition)
    currentNewDomestics<-
previousNewDomestics*sourceSurv[2:18,]^.5*capAfrSurv[2:18,]*domestSurv[2:18,]^(3/10)
    DT[kkk,3]<-sum(previousNewDomestics-currentNewDomestics)
    midNewDomestics<-(previousNewDomestics+currentNewDomestics)/2
    births<-midNewDomestics[3:11,1]*(2.5*sourceFert[3:11]+1.5*newDomFert[3:11]+1*domestFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewDomestics[17,]<-currentNewDomestics[16,]+currentNewDomestics[17,]
    currentNewDomestics[2:16,]<-currentNewDomestics[1:15,]
    currentNewDomestics[1,]<-c(newFemales,newMales)*sourceSurv[1,]^.5*capAfrSurv[1,]*domestSurv[1,]^(3/10)
    BT[kkk,3]<-newFemales+newMales
    DT[kkk,3]<-DT[kkk,3]+sum(c(newFemales,newMales)-currentNewDomestics[1,])

    previousDomestics<-currentDomestics
    currentDomestics<-previousDomestics*domestSurv[2:18,]
    DT[kkk,4]<-sum(previousDomestics-currentDomestics)
    midDomestics<-(previousDomestics+currentDomestics)/2
    births<-midDomestics[3:11,1]*5*domestFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
    currentDomestics[2:16,]<-currentDomestics[1:15,]
    currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
    currentDomestics<-currentDomestics+currentNewDomestics
    BT[kkk,4]<-newFemales+newMales
    DT[kkk,4]<-DT[kkk,4]+sum(c(newFemales,newMales)-currentDomestics[1,])

    previousNewAbrExp<-captives*partition
    currentNewAbrExp<-
previousNewAbrExp*sourceSurv[2:18,]^(1/2)*capAfrSurv[2:18,]*capAbrSurv[2:18,]*exportSurv[2:18,]^(1/10)
    DT[kkk,5]<-sum(previousNewAbrExp-currentNewAbrExp)
    midNewAbrExp<-(previousNewAbrExp+currentNewAbrExp)/2
    births<-
midNewAbrExp[3:11,1]*(2.5*sourceFert[3:11]+newAfrExpFert[3:11]+newAbrExpFert[3:11]+.5*exportFert[3:11])
```

```
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewAbrExp[17,]<-currentNewAbrExp[16,]+currentNewAbrExp[17,]
    currentNewAbrExp[2:16,]<-currentNewAbrExp[1:15,]
    currentNewAbrExp[1,]<-
c(newFemales,newMales)*sourceSurv[1,]^(1/2)*capAfrSurv[1,]*capAbrSurv[1,]*exportSurv[1,]^(1/10)
    BT[kkk,5]<-newFemales+newMales
    DT[kkk,5]<-DT[kkk,5]+sum(c(newFemales,newMales)-currentNewAbrExp[1,])

    ET[kkk]<-sum(currentNewAbrExp)

    ARPT[,,kkk]<-currentSource+currentCaptor+currentDomestics
    ADPT[,,kkk]<-currentDomestics
    AEPT[,,kkk]<-currentNewAbrExp
    ANDPT[,,kkk]<-currentNewDomestics
    ANAEPT[,,kkk]<-currentNewAbrExp
  }

  endPopRatio<-mostRecentPop/sum(ARPT[,,numIter])
  defCaptives<-(CT[numIter-1]+CT[numIter])*endPopRatio
  defExports<-(ET[numIter-1]+ET[numIter])*endPopRatio
  PR<-decExports/defExports
  captExpRela<-getCaptExpRela(defaultArray,captureSize,partition,numIter)
  CCM<-captExpRela[which.min(abs(decExports/defExports-captExpRela[,2])),1]*currCaptMult
  CT<-defCaptives
  ET<-defExports


return(list(ARPT=ARPT,ADPT=ADPT,AEPT=AEPT,ANDPT=ANDPT,ANAEPT=ANAEPT,BT=BT,CT=CT,DT
=DT,ET=ET,CCM=CCM,PR=PR))
}

getCaptExpRela<-function(defaultArray,capture,partition,numIter){

  captRela<-numeric(2*301)
  dim(captRela)<-c(301,2)
  captRela[,1]<-seq(0,3,by=.01)

  defaultArray[1:17,1,3]->sourceFert
  defaultArray[1:17,1,4]->captorFert
  defaultArray[1:17,1,5]->domestFert
  defaultArray[1:17,1,6]->exportFert
  defaultArray[1:17,1,7]->newDomFert
  defaultArray[1:17,1,8]->newAfrExpFert
  defaultArray[1:17,1,9]->newAbrExpFert
  defaultArray[,,10]->sourceSurv
  defaultArray[,,11]->captorSurv
  defaultArray[,,12]->domestSurv
  defaultArray[,,13]->exportSurv
  defaultArray[,,14]->capAfrSurv
  defaultArray[,,15]->capAbrSurv

  for(iiii in captRela[,1]){
    defaultArray[1:17,,1]->currentSource
    defaultArray[1:17,,2]->currentCaptor
```

```
captureSize<-iiii*capture

currentSource[,2]<-.95109*currentSource[,2]      ##      modify males according to initial sex ratio = .95109
currentCaptor[,2]<-.95109*currentCaptor[,2]

#############################################################################################
##      necessary declarations and initializations for the simulation
#############################################################################################

currentNewDomestics<-numeric(34)
dim(currentNewDomestics)<-c(17,2)
currentDomestics<-numeric(34)
dim(currentDomestics)<-c(17,2)
currentNewAfrExp<-numeric(34)
dim(currentNewAfrExp)<-c(17,2)
currentNewAbrExp<-numeric(34)
dim(currentNewAbrExp)<-c(17,2)
exportTracker<-numeric(2)


#############################################################################################
##      Begin the first iteration through 5 year periods of time
#############################################################################################

for (jjjj in 1:numIter){
  previousSource<-currentSource
  currentSource<-previousSource*sourceSurv[2:18,]
  midSource<-(previousSource+currentSource)/2
  captives<-midSource*5*captureSize
  currentSource<-currentSource-captives
  midSource<-(previousSource+currentSource)/2
  births<-midSource[3:11,1]*5*sourceFert[3:11]
  newFemales<-sum(births)
  newMales<-sum(births)*1.03
  currentSource[17,]<-currentSource[16,]+currentSource[17,]
  currentSource[2:16,]<-currentSource[1:15,]
  currentSource[1,]<-c(newFemales,newMales)*sourceSurv[1,]

  previousCaptor<-currentCaptor
  currentCaptor<-previousCaptor*captorSurv[2:18,]
  midCaptor<-(previousCaptor+currentCaptor)/2
  births<-midCaptor[3:11,1]*5*captorFert[3:11]
  newFemales<-sum(births)
  newMales<-sum(births)*1.03
  currentCaptor[17,]<-currentCaptor[16,]+currentCaptor[17,]
  currentCaptor[2:16,]<-currentCaptor[1:15,]
  currentCaptor[1,]<-c(newFemales,newMales)*captorSurv[1,]

  previousNewDomestics<-captives*(1-partition)
  currentNewDomestics<-
previousNewDomestics*sourceSurv[2:18,]^.5*capAfrSurv[2:18,]*domestSurv[2:18,]^(3/10)
  midNewDomestics<-(previousNewDomestics+currentNewDomestics)/2
  births<-midNewDomestics[3:11,1]*(2.5*sourceFert[3:11]+1.5*newDomFert[3:11]+1*domestFert[3:11])
  newFemales<-sum(births)
  newMales<-sum(births)*1.03
  currentNewDomestics[17,]<-currentNewDomestics[16,]+currentNewDomestics[17,]
```

```
    currentNewDomestics[2:16,]<-currentNewDomestics[1:15,]
    currentNewDomestics[1,]<-
c(newFemales,newMales)*sourceSurv[1,]^.5*capAfrSurv[1,]*domestSurv[1,]^(3/10)

    previousDomestics<-currentDomestics
    currentDomestics<-previousDomestics*domestSurv[2:18,]
    midDomestics<-(previousDomestics+currentDomestics)/2
    births<-midDomestics[3:11,1]*5*domestFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
    currentDomestics[2:16,]<-currentDomestics[1:15,]
    currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
    currentDomestics<-currentDomestics+currentNewDomestics

    previousNewAbrExp<-captives*partition
    currentNewAbrExp<-
previousNewAbrExp*sourceSurv[2:18,]^(1/2)*capAfrSurv[2:18,]*capAbrSurv[2:18,]*exportSurv[2:18,]^(1/10)
    midNewAbrExp<-(previousNewAbrExp+currentNewAbrExp)/2
    births<-
midNewAbrExp[3:11,1]*(2.5*sourceFert[3:11]+newAfrExpFert[3:11]+newAbrExpFert[3:11]+.5*exportFert[3:11])
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentNewAbrExp[17,]<-currentNewAbrExp[16,]+currentNewAbrExp[17,]
    currentNewAbrExp[2:16,]<-currentNewAbrExp[1:15,]
    currentNewAbrExp[1,]<-
c(newFemales,newMales)*sourceSurv[1,]^(1/2)*capAfrSurv[1,]*capAbrSurv[1,]*exportSurv[1,]^(1/10)

    if(jjjj==(numIter-1))exportTracker[1]<-sum(currentNewAbrExp)
    if(jjjj==(numIter))exportTracker[2]<-sum(currentNewAbrExp)
   }

   captRela[which(captRela[,1]==iiii),2]<-sum(exportTracker)
  }

  captRela[,2]<-captRela[,2]/captRela[which(captRela[,1]==1),2]

  maxCapt<-which.max(captRela[,2])
  captRela<-captRela[1:maxCapt,]

  return(captRela)
}

terrType2<-function(defaultArray,decData,numIter,numDec,firstDec){

  ##############################################################################
  ##        Initialize aggregate output storage
  ##############################################################################
  decPopVect<-numeric(numDec)

  ##############################################################################
  ##        Initialize territorial output storage
  ##############################################################################
  allRegPopTracker<-numeric(numDec*17*2*numIter)
  dim(allRegPopTracker)<-c(numDec,17,2,numIter)
  newBirths<-numeric(numDec)
```

```
  newDeaths<-numeric(numDec)

  ##############################################################################################
  ##        Convert decData to the appropriate format
  ##############################################################################################
  terr<-as.character(decData[1])
  initPop<-as.numeric(decData[8])
  decs<-seq(firstDec,firstDec-10*(numDec-1),by=-10)

  mostRecentPop<-initPop
  for(kkkk in 1:numDec){
   callToSim<-simpleSim(defaultArray,numIter)
   allRegPopTracker[kkkk,,,]<-callToSim$ARPT
   birthTracker<-callToSim$BT
   deathTracker<-callToSim$DT
   captiveTracker<-callToSim$CT
   exportTracker<-callToSim$ET
   endPopRatio<-mostRecentPop/sum(allRegPopTracker[kkkk,,,numIter])
   allRegPopTracker[kkkk,,,]<-allRegPopTracker[kkkk,,,]*endPopRatio
   mostRecentPop<-sum(allRegPopTracker[kkkk,,,numIter-2])
   decPopVect[kkkk]<-mostRecentPop
   newBirths[kkkk]<-(birthTracker[numIter-1]+birthTracker[numIter])*endPopRatio
   newDeaths[kkkk]<-(deathTracker[numIter-1]+deathTracker[numIter])*endPopRatio
  }

  ##############################################################################################
  ##        Territorial output
  ##############################################################################################
  forRates<-cbind(initPop,decPopVect)
  midPeriodPops<-(forRates[1:(length(forRates)-1)]+forRates[2:length(forRates)])/2
  arpt<-allRegPopTracker[,,,numIter-2]

  temp<-data.frame(Region=terr)
  write.table(temp,paste("",terr,".csv",sep=""),row.names = FALSE, col.names = TRUE)
  for(z in 1:numDec){
   temp<-data.frame(Year=decs[z])
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AdultSexRatio=sum(arpt[z,4:11,2])/sum(arpt[z,3:8,1]))
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualBirths=newBirths[z]/10)
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualBirthRate=newBirths[z]/(10*midPeriodPops[z]))
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualDeaths=newDeaths[z]/10)
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
   temp<-data.frame(AnnualDeathRate=c(newDeaths[z]/(10*midPeriodPops[z]),""))
   write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  }
  return(decPopVect)
}

terrType3<-function(defaultArray,decData,importArray,numIter,numDec,firstDec){

  defaultArray[1:17,1,5]->domestFert
  defaultArray[,,12]->domestSurv
```

```
decPopVect<-numeric(numDec)
##############################################################################################
##        Initialize territorial output storage
##############################################################################################
allDomPopTracker<-numeric(numDec*17*2)
dim(allDomPopTracker)<-c(numDec,17,2)
allRegPopTracker<-numeric(numDec*17*2*numIter)
dim(allRegPopTracker)<-c(numDec,17,2,numIter)
newBirths<-numeric(numDec)
newDeaths<-numeric(numDec)

##############################################################################################
##        Convert decData to the appropriate format
##############################################################################################
terr<-as.character(decData[1])
initPop<-as.numeric(decData[8])
decs<-seq(firstDec,firstDec-10*(numDec-1),by=-10)

##############################################################################################
##        Calculate Slave Descended Population
##############################################################################################
allDomPopTracker[numDec,,]<-importArray[numDec,,]
for(iiiii in (numDec-1):1){
  for(jjjjj in 1:2){
    if(jjjjj==1){previousDomestics<-allDomPopTracker[iiiii+1,,]}
    if(jjjjj==2){previousDomestics<-currentDomestics}
    currentDomestics<-previousDomestics*domestSurv[2:18,]
    newDeaths[iiiii+1]<-newDeaths[iiiii+1]+sum(previousDomestics-currentDomestics)
    midDomestics<-(previousDomestics+currentDomestics)/2
    births<-midDomestics[3:11,1]*5*domestFert[3:11]
    newFemales<-sum(births)
    newMales<-sum(births)*1.03
    currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
    currentDomestics[2:16,]<-currentDomestics[1:15,]
    currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
    newBirths[iiiii+1]<-newBirths[iiiii+1]+newFemales+newMales
    newDeaths[iiiii+1]<-newDeaths[iiiii+1]+sum(c(newFemales,newMales)-currentDomestics[1,])
  }
  allDomPopTracker[iiiii,,]<-importArray[iiiii,,]+currentDomestics
}

##############################################################################################
##        Calculate Final Slave Descended Population
##############################################################################################
finalDomPop<-numeric(17*2)
finalDomPop<-c(17,2)
for(kkkkk in 1:2){
  if(kkkkk==1){previousDomestics<-allDomPopTracker[1,,]}
  if(kkkkk==2){previousDomestics<-currentDomestics}
  currentDomestics<-previousDomestics*domestSurv[2:18,]
  newDeaths[1]<-newDeaths[1]+sum(previousDomestics-currentDomestics)
  midDomestics<-(previousDomestics+currentDomestics)/2
  births<-midDomestics[3:11,1]*5*domestFert[3:11]
  newFemales<-sum(births)
  newMales<-sum(births)*1.03
  currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
```

```
  currentDomestics[2:16,]<-currentDomestics[1:15,]
  currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
  newBirths[1]<-newBirths[1]+newFemales+newMales
  newDeaths[1]<-newDeaths[1]+newDeaths[1]+sum(c(newFemales,newMales)-currentDomestics[1,])
  finalDomPop<-finalDomPop+currentDomestics
}

mostRecentPop<-initPop-sum(finalDomPop)
for(iiiiii in 1:numDec){
  callToSim<-simpleSim(defaultArray,numIter)
  allRegPopTracker[iiiiii,,,]<-callToSim$ARPT
  birthTracker<-callToSim$BT
  deathTracker<-callToSim$DT
  endPopRatio<-mostRecentPop/sum(allRegPopTracker[iiiiii,,,numIter])
  allRegPopTracker[iiiiii,,,]<-allRegPopTracker[iiiiii,,,]*endPopRatio
  mostRecentPop<-sum(allRegPopTracker[iiiiii,,,numIter-2])
  decPopVect[iiiiii]<-sum(allRegPopTracker[iiiiii,,,numIter-2])+sum(allDomPopTracker[iiiiii,,])
  newBirths[iiiiii]<-newBirths[iiiiii]+(birthTracker[numIter-1]+birthTracker[numIter])*endPopRatio
  newDeaths[iiiiii]<-newDeaths[iiiiii]+(deathTracker[numIter-1]+deathTracker[numIter])*endPopRatio

}

##############################################################################################
##        Territorial output
##############################################################################################
forRates<-cbind(initPop,decPopVect)
midPeriodPops<-(forRates[1:(length(forRates)-1)]+forRates[2:length(forRates)])/2
arpt<-allRegPopTracker[,,,numIter-2]+allDomPopTracker
adpt<-allDomPopTracker

temp<-data.frame(Region=terr)
write.table(temp,paste("",terr,".csv",sep=""),row.names = FALSE, col.names = TRUE)
for(zz in 1:numDec){
  temp<-data.frame(Year=decs[zz])
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(AdultSexRatio=c(sum(arpt[zz,4:11,2])/sum(arpt[zz,3:8,1]),"DomesticSlavePopulation"))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(Female=adpt[zz,,1],Male=adpt[zz,,2])
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE,sep = ",")
  temp<-data.frame(TotalFemaleSlaves=sum(adpt[zz,,1]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalMaleSlaves=sum(adpt[zz,,2]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalDomesticSlaves=sum(adpt[zz,,]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(AnnualBirths=newBirths[zz]/10)
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(AnnualBirthRate=newBirths[zz]/(10*midPeriodPops[zz]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(AnnualDeaths=newDeaths[zz]/10)
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(AnnualDeathRate=c(newDeaths[zz]/(10*midPeriodPops[zz]),""))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
}

return(decPopVect)
```

```
}

terrType4<-function(defaultArray,importArray,terr, numDec,firstDec){

 defaultArray[1:17,1,5]->domestFert
 defaultArray[,,12]->domestSurv

 ##############################################################################################
 ##        Initialize territorial output storage
 ##############################################################################################
 allDomPopTracker<-numeric(numDec*17*2)
 dim(allDomPopTracker)<-c(numDec,17,2)

 ##############################################################################################
 ##        Calculate Slave Descended Population
 ##############################################################################################
 allDomPopTracker[numDec,,]<-importArray[numDec,,]
 for(jjjjj in (numDec-1):1){
  for(kkkkkk in 1:2){
   if(kkkkkk==1){previousDomestics<-allDomPopTracker[jjjjjj+1,,]}
   if(kkkkkk==2){previousDomestics<-currentDomestics}
   currentDomestics<-previousDomestics*domestSurv[2:18,]
   midDomestics<-(previousDomestics+currentDomestics)/2
   births<-midDomestics[3:11,1]*5*domestFert[3:11]
   newFemales<-sum(births)
   newMales<-sum(births)*1.03
   currentDomestics[17,]<-currentDomestics[16,]+currentDomestics[17,]
   currentDomestics[2:16,]<-currentDomestics[1:15,]
   currentDomestics[1,]<-c(newFemales,newMales)*domestSurv[1,]
  }
  allDomPopTracker[jjjjjj,,]<-importArray[jjjjjj,,]+currentDomestics
 }

 ##############################################################################################
 ##        Territorial output
 ##############################################################################################
 adpt<-allDomPopTracker
 #terr<-"Americas"
 decs<-seq(firstDec,firstDec-10*(numDec-1),by=-10)
 temp<-data.frame(Region=terr)
 write.table(temp,paste("",terr,".csv",sep=""),row.names = FALSE, col.names = TRUE)
 for(zzz in 1:numDec){
  temp<-data.frame(Year=c(decs[zzz],"DomesticSlavePopulation"))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(Female=adpt[zzz,,1],Male=adpt[zzz,,2])
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE,sep = ",")
  temp<-data.frame(TotalFemaleSlaves=sum(adpt[zzz,,1]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalMaleSlaves=sum(adpt[zzz,,2]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
  temp<-data.frame(TotalDomesticSlaves=sum(adpt[zzz,,]))
  write.table(temp,paste("",terr,".csv",sep=""),append=TRUE, row.names = FALSE, col.names = TRUE)
 }

}
```

```
newBPMain_pop_sex<-function(inFile1,inFile2,outFile1,outFile2,numIter,numDec,firstDec){

  ##############################################################################
  ##      inFile is a character string naming the(path and) file
  ##      where input is stored, e.g. "fileName.csv"
  ##
  ##      outFile is a character string naming the(path and) file
  ##      where output is stored, e.g. "fileName.csv"
  ##
  ##      numIter is the number of 5 year iterations conducted
  ##      at each stage of the simulation
  ##
  ##      numDec is the number of decades to project back
  ##
  ##      firstDec is the first decade for which we want a back
  ##      projected population
  ##############################################################################

  ##############################################################################
  ##      Read in default fertility, population, partition, capture, and
  ##      survival arrays
  ##      -fertility files are in the usual 17x1 format
  ##      -population, partition, and captureSize files are in 34x1 format
  ##      -survival files are in 36x1 format;
  ##      1st entry = 0-1
  ##      2nd entry = 1-5
  ##      3rd entry = 5-10 ...
  ##      18th entry= 80+ (we are allowing one to gain entry to the next 80+ group either
  ##      by being 80+ and surviving the current period, or by being 75-80 and surviving
  ##      the current period) (note that capAfr and capAbr are 1 year rates, all other
  ##      survival rates are 5 year)
  ##############################################################################

  defaultArray<-windDefault()
  partitionType1<-as.matrix(read.table(file="pcf24m49.dat",skip=1))
  dim(partitionType1)<-c(17,2)
  partitionType2<-as.matrix(read.table(file="pcf27m14.dat",skip=1))
  dim(partitionType2)<-c(17,2)


  ##############################################################################
  ##      Convert data in inFile to a data frame
  ##############################################################################

  decData<-read.csv(inFile1,header=TRUE,as.is=c(1,2))
  decData<-data.frame(decData)
  attach(decData)

  slaveTradeMatrix<-read.csv(inFile2,as.is=c(1))
  slaveTradeMatrix<-as.matrix(slaveTradeMatrix[,2:length(slaveTradeMatrix[1,])])
  slaveTradeMatrix<-data.frame(slaveTradeMatrix)

  ##############################################################################
  ##      Create arrays in which all calculated values are stored
  ##############################################################################
```

```
exportArray<-numeric(sum(TerritoryType==1)*numDec*17*2)
dim(exportArray)<-c(sum(TerritoryType==1),numDec,17,2)

decPopArray<-numeric(length(decData[,1])*numDec)
dim(decPopArray)<-c(length(decData[,1]),numDec)

sexNAFEpop<-numeric(length(decData[,1])*numDec)
dim(sexNAFEpop)<-c(length(decData[,1]),numDec)

##############################################################################
##      Calls to the terrType functions fill the above output arrays and also
##      generate individual territorial output files
##      terrType1: no imports, exports, source and captor pop (Senegal-Mozambique)
##      terrType2: no imports, no exports, captor pop only (Madagascar,sAfrica)
##      terrType3: imports, no exports, captor and domestic pop (nAfrica)
##      terrType4: imports, no exports, domestic pop only (America)
##############################################################################

terr1part1<-which((TerritoryType==1)&(PartType==1))

for(i in terr1part1){
 temp<-terrType1(defaultArray,partitionType1,decData[i,],numIter,numDec,firstDec)
 exportArray[i,,,]<-temp$exportArray
 decPopArray[i,]<-temp$decPopVect
 sexNAFEpop[i,]<-temp$sexNAFEpop
 sexNAFEpop[i,]<-temp$sexNAFEpop
}

terr1part2<-which((TerritoryType==1)&(PartType==2))
for(i in terr1part2){
 temp<-terrType1(defaultArray,partitionType2,decData[i,],numIter,numDec,firstDec)
 exportArray[i,,,]<-temp$exportArray
 decPopArray[i,]<-temp$decPopVect
 sexNAFEpop[i,]<-temp$sexNAFEpop
 sexNAFEpop[i,]<-temp$sexNAFEpop
}

terr2<-which(TerritoryType==2)
for(i in terr2){
 decPopArray[i,]<-terrType2(defaultArray,decData[i,],numIter,numDec,firstDec)
}

##############################################################################
##      Tally imports by territory
##############################################################################


attach(slaveTradeMatrix)
importArray<-numeric((sum(TerritoryType==3)+2)*numDec*17*2)
dim(importArray)<-c((sum(TerritoryType==3)+2),numDec,17,2)
for(i in 1:(sum(TerritoryType==3)+2)){
 importArray[i,,,]<-apply(slaveTradeMatrix[,i]*exportArray,c(2,3,4),sum)
}

terr3<-which(TerritoryType==3)
for(i in terr3){
```

```
  decPopArray[i,]<-terrType3(defaultArray,decData[i,],importArray[which(terr3==i),,],numIter,numDec,firstDec)
 }

 k<-length(importArray[,1,1,1])
 terr <- c("Americas","Indian Ocean")
 for(i in 1:2){
  terrType4(defaultArray,importArray[k-2+i,,],terr[i],numDec,firstDec)
 }
 ##############################################################################
 ##       Begin aggregate output
 ##############################################################################

 decs<-seq(firstDec,firstDec-(10*(numDec-1)),by=-10)
 colnames(decPopArray)<-as.character(decs)
 terrMat<-cbind(Territory,Region,decPopArray)
 terrMat<-cbind(Territory,Region,decPopArray)
 terrMat1<-cbind(Territory,Region,sexNAFEpop)
 write.table(terrMat,outFile1,row.names=FALSE,col.names = TRUE, sep = ",")

 write.table(terrMat1,outFile2,row.names=FALSE,col.names = TRUE, sep = ",")

}

#Back to 1650
newBPMain_pop_sex('inFile1890.PM9.csv','slaveTradeMatrix.csv','outFile1890_model1.PM9.csv','sex_ratio_model
1.PM9.csv',8,25,1890)
newBPMain('inFile1890.PM9.csv','slaveTradeMatrix.csv','outFile1890.PM9.csv',8,25,1890)

#Test Run
newBPMain('inFileBeg1890_2.csv','slaveTradeMatrix.csv','outFileBeg1890.csv',4,24,1890)

#19 goes to 1710

decData<-read.csv('inFileBeg1890_3.csv',header=TRUE,as.is=c(1,2))
decData<-data.frame(decData)
```

Appendix F

TAST: Technical Report I

Yun Zhang 08-

13-2013

1 Overview

The primary goal is to impute the embarkation count for a given region within a certain decade. The voyages that may contribute to the total embarkation count within a given region and decade can be partitioned into sixteen categories based on the existence of records in the variables: embarkation port, decade, embarkation count and arrival count. The strategy is to compute the total embarkation count for each subset of data partitioned by missing type. Table 1 outlines the methods that will be employed in the treatment of each subset. Then the individual contributions are added to the current total and the estimated variance is updated by summing the variances. This implicitly assumes that these totals are independent, but also provides lower bounds of the estimate of variance.

2 Data Preparation

In the data preparation stage, we check for known inconsistencies in the dataset. One is the situation in which the arrival count is much greater than the embarkation count. We treat these cases by keeping arrival count but labelling embarkation count as missing. In fact, records with arrival count to embarkation count ratio between 0.9 and 1 are also suspicious. But we don't edit them for now.

3 Model Specification

Note that all the models we introduce below are built for each decade separately except for the decade assignment model.

3.1 Ratio Estimate

To illustrate the method, we perform a ratio estimate for the embarkation count($\{E_i\}$) against the arrival count($\{A_i\}$). We would like to estimate the ratio β if the assumed model is

$$E_i = \beta A_i + E_i \tag{1}$$

where $E_i \sim n(0, \sigma^2)$. The estimate for β with variance is given by,

	Port w/ Decade	Decade w/o Port	Port w/o Decade	Neither
Embark.	Direct Estimate	Multin.	Multin.	Multin.
Arriv. w/o Embark.	Ratio & SAE	Ratio & Multin.	Ratio & Multin.	Ratio & Multin.
Neither	Mean & SAE	Mean & Multin.	Mean & Multin.	Mean & Multin.

Table 1: SAE - small area estimation, Ratio - ratio estimate, Multin. - propagation through the

multinomial model, Mean - using the mean as an estimate

$$\hat{\beta} = \frac{\sum_{i \in T} E_i}{\sum_{i \in T} A_i} \tag{2}$$

$$\mathbf{V}(\hat{\beta}) = \left(1 - \frac{n}{N}\right) \frac{1}{n \bar{A}_N^2} \frac{\sum_{i \in T} (E_i - \hat{\beta} A_i)^2}{n - 1} \tag{3}$$

where T is our training sample (those with both records for embarkation and arrival count); n and N are the size of the training sample and all the samples with the arrival count respectively; $\bar{A}_N$ is the mean of the arrival counts amongst all those voyages with the count. The covariance between the individual port ratio estimate and the pooled ratio estimate will be needed in the shrinkage procedure, and is given by,

$$Cov(\beta_p, \beta) = \mathbf{V}(\beta_i) \frac{\sum_{i \in p} A_i}{\sum_{i \in \cup_j p_j} A_i} \tag{4}$$

Notice that the implicit assumption with this method is that the missingness of the embarkation count can be considered to be randomized, hence, making the training set a random sample of all the voyages with the arrival count.

In the cases with both the port and decade records small area estimation will be used, yielding a modified estimate of β. We are now able to estimate the net embarkation count(E_M), for voyages containing the AC and missing the EC, with estimated variance by,

$$\hat{E_M} = \hat{\beta} \sum_{i \in M} A_i \tag{5}$$

$$\mathbf{V}(E_M) = \left(\sum_{i \in M} A^2\right) \mathbf{V}(\hat{\beta}) \tag{6}$$

3.2 Mean Estimate

The mean estimate is a very straightforward standard calculation. For a given embarkation region, p, we will denote the mean of the embarkation count in our training sample (those with records for embarkation) as $\bar{E}_p$, and size of training sample as $|p|$

$$\mathbf{V}(\bar{E}_p) = \frac{\sum_{i \in p} (E_i - \bar{E}_p)^2}{|p| - 1} \frac{1}{|p|} \tag{7}$$

$$Cov(\bar{E}_p, \bar{E}) = \mathbf{V}(\bar{E}_p) \frac{|p|}{\sum_j |p_j|} \tag{8}$$

This also undergoes the small area estimate modifications in the sparser cases, with both region and decade records.

3.3 Small Area Estimation

We use small area estimation when performing either an estimation with a region mean, or via a ratio estimate. In both cases we use a technique, called composition or more generally shrinkage, by which the estimator is replaced by a linear combination($\hat{\theta}_r^C$) of the regional estimator and the estimator from the pooled regions.

$$\hat{\theta}_r^C = (1 - b)\hat{\theta}_r + b\hat{\theta} \tag{9}$$

We will construct an optimal estimate for b, b_r, based on previously computed estimates for the region estimate variance, $\mathbf{V}(\hat{\theta}_r) = v_r$, the pooled regions estimate variance, $\mathbf{V}(\hat{\theta}) = v$, and the covariance between the region and the pooled region estimates, $cov(\hat{\theta}, \hat{\theta}_r) = c_r$.

$$b_r = \frac{v_r - c_r}{v_r + v - 2c_r + \sigma_B^2} \tag{10}$$

$$\hat{\sigma}_B^2 = \frac{1}{n}(S - \sum_{r=1}^{R} n_r v_r) \tag{11}$$

$$S = \sum_{r=1}^{R} n_r(\hat{\theta}_r - \hat{\theta})^2 \tag{12}$$

where n_r and n are the number of voyages in each region and the total number of voyages respectively. On the rare occasion that this estimator is negative then we conclude that the actual value is very small, in which case, $\hat{\theta}$ should be used to estimate θ_r.

3.4 Region/Decade Assignment Model

We will call the idea of assigning embarkation counts without region or decade or both values according to a multinomial distribution the " region/decade assignment model" . Some mention should be made as to what actual imputations are being performed. The missing regions are not being imputed for given voyages, rather we would like an estimate of each region' s contributions to the pool of voyages with missing region records. Consider that the region of departure may take one of several discrete values, which we index 1, 2...I. Denote the embarkation counts from region i in decade j as N_{ij}, and the embarkation counts with missing region in decade j as n_j. Assuming conditional on n_j, each region' s contributions $n_{1j}, \cdots, n_{Ij}$ follow multinomial distribution with probabilities $q_1, q_2, \ldots q_I$, then the maximal likelihood estimates of q_i and variances are given by

$$\hat{q}_i = \frac{N_{ij}}{\sum_{i=1}^{I} N_{ij}} \tag{13}$$

$$\hat{n}_{ij} = n_j \hat{q}_i \tag{14}$$

$$\mathbf{V}(\hat{q}_i) \approx \frac{\hat{q}_i(1 - \hat{q}_i)}{\sum_{i=1}^{I} N_{ij}} \tag{15}$$

$$\mathbf{V}(\hat{n}_{ij}) \approx \mathbf{V}(\hat{n}_j)\mathbf{V}(\hat{q}_i) + \hat{n}_j^2 \mathbf{V}(\hat{q}_i) + \hat{q}_i^2 \mathbf{V}(\hat{n}_j) \tag{16}$$

One additional remark is that N_{ij} and n_j are computed using the most recent calculation(imputation) of the embarkation slave count (from those samples with no missing in region and decade, and samples with missing region respectively)

Identical procedures are performed to handle voyages with missing decades.

Consider decade of departure may take one of several discrete values, which we index 1, 2...J. Denote the embarkation counts from region i in decade j as N^I_{ij}, and the embarkation counts with missing decade for region i as n_i. Assuming conditional on n_i, each decade' s contributions $n^I_{i1}, \cdots, n^I_{iJ}$ follow multinomial distribution with probabilities $p_1, q_2, \ldots p_J$, then the maximal likelihood estimates of q_j and variances are given by

$$\hat{q}_j = \frac{N^I_{ij}}{\sum_{j=1}^{J} N^I_{ij}} \tag{17}$$

$$\hat{n}^I_{ij} = n_i \hat{q}_j \tag{18}$$

$$\mathbf{V}(\hat{q}_j) \approx \frac{\hat{q}_j(1 - \hat{q}_j)}{\sum_{j=1}^{J} N^I_{ij}} \tag{19}$$

$$\mathbf{V}(\hat{n}^I_{ij}) \approx \mathbf{V}(\hat{n}_i)\mathbf{V}(\hat{q}_j) + \hat{n}_i^2 \mathbf{V}(\hat{q}_j) + \hat{q}_j^2 \mathbf{V}(\hat{n}_i) \tag{20}$$

It should be noted that N^I_{ij} is not equal to N_{ij} for the reason that $N^I_{ij} = N_{ij} + \hat{n_{ij}}$. Equivalently, N^I_{ij} can be thought of the updated version of N_{ij}. Likewise, if both port and decade are missing then we estimate the percentage of these embarkation counts that contribute to each region and decade in the analogous way using the most updated imputations.

4 Discussion of the Model

To determine the decade-wise and port-wise slave exportation count, we imputed the EC using a complex method with many independent parts. Hence, many modelling assumptions were made, corresponding to each estimation.

The most important assumption is random missingness. While in most of the situations, this assumption is reasonable, the assumption that the missingness of the region is not confounded by the EC or the region itself is somewhat questionable. Same considerations rise as to missingness of the decade. These are difficult assumptions to test, as the missing value may not be observed when they are missing.

There are also instances where we use samples with a certain type of missingness repeatedly to train parameters that will allow the imputation of EC from samples with other types of missingness. We ignore the variance brought by repeated measurements when we estimate the standard error of the imputations for convenience.

Note that we only apply Decade assignment model to decades with more than 200 voyages(which accounts for a vast majority of the voyages). This suggests underestimate of Embarkation Count for those decades with less than 200 voyages.

This paragraph presents discussion of the Region/Decade Assignment Model. We take the miss- ing port model as example here. The assumption that persons embarked on voyages with missing region records fell independently into any regional category is invalid for the fact that persons em- barked on the same voyage can fall in only one region category. This can be remedied by using voyage as the unit instead, that is, assuming that voyages with missing port records independently fall in any port category. All the calculations are similar. But to calculate contributions of embarka- tion count for each port, we need to further assume number of persons embarked on each voyage are roughly the same, which can't be validated. Two version of results are presented since either way has some drawbacks. Also note that Port/decade assignment model can be optimized further by taking advantage of our knowledge in nation.

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